THE
JOURNAL OF GEOLOGY

OCTOBER–NOVEMBER, 1906

NOTES ON THE GEOLOGICAL SECTION OF IOWA

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The columnar section is not drawn to scale. The approximate average thickness is indicated in the appropriate column.

The Sioux quartzite occupies only a few acres in the northwest corner of the state, and in this locality it is Cretaceous sediments which are found, in place, abutting against it. That it is pre-Cambrian in age admits of no doubt, and that it is the equivalent of the Baraboo quartzite of Wisconsin is equally certain. The 25 feet exposed in Iowa is only a small part of the thickness of this formation.

The Cambrian sandstones are exposed by the erosion of the river valleys in the northeastern part of the state. The basal contact with the Algonkian quartzites is not seen in Iowa; a thickness of fully 700 feet of this formation lies below the level of the Mississippi River at Lansing and New Albin. This sandstone has been referred to the Upper Cambrian, or Potsdam series, in the geological reports of Iowa and Wisconsin. The special formation name, St. Croix, and the names applied to the smaller divisions, have been adopted from the reports on the geology of Minnesota.

Lower Magnesian.—This term is retained tentatively for the sediments lying between the top of the Cambrian, the Jordan sandstone, and the very consistent geologic unit which has been universally recognized under the name of the St. Peter sandstone. The New Richmond sandstone, when present, divides the Lower Mag-

System	Series Name	Formation Name		Columnar Section	Thickness in Feet	Character of Rocks
Quaternary.	Pleistocene	Wisconsin			0–30+	Boulder clay, pale yellow, very calcareous
		Peorian				Soil band
		Iowan			0–30+	Boulder clay, yellow, with very large boulders.
		Sangamon				Soil, peat and forest beds.
		Illinoian			0–100+	Boulder clay, yellow.
		Yarmouth				Soil, peat and forest beds.
		Kansan			0–400+	Boulder clay, blue, jointed, with interbedded streaks & pockets of sand & gravel
		Aftonian			0–40+	Peat & forest beds, soil bands, aqueous gravels
		Pre-Kansan			0–30+	Boulder clays, dark, friable.
Cretaceous.	Upper Cretaceous	Colorado			150	Shales with soft limestones, in places chalky.
		Dakota			100	Sandstones.
Permian.		Gypsum Series	Red Beds		20	Red shales and sandstones.
			Gypsum		20	Gypsum
Carboniferous.	Pennsylvanian	Missourian			600	Shales and limestones.
		Des Moines			750	Shales and sandstones with some beds of limestone.
	Mississippian	St. Louis			100	Limestone, sandstone & marly shales.
		Osage or Augusta			265	Locally oolitic limestone with heavy bands of chert, some shale.
		Kinderhook			120	Shale, sandstone and limestone, limestone in places calcic.
Devonian	Neo-Devonian	State Quarry Lime Creek Sweetland Creek			(40 (120 (20)	Limestone, mostly brecciated cherts Marly shales (heavily developed features east Clay correspondents for the Meso Devonian) Shale
	Meso-Devonian	Cedar Valley			100	Limestones, shaly limestones, some dolomite in the northern counties
		Wapsipinicon			60–75	Limestones, shales, & shaly limestones
Silurian	Niagara	Gower			120	Dolomite, not very fossiliferous. Le Claire phase extensively cross-bedded.
		Hopkinton			220	Dolomite, very fossiliferous, in places
Ordovician	Trenton	Maquoketa			200	Shale, shaly limestones, and, locally, beds of dolomite.
		Galena			340	Dolomite in places, in places unaltered limestones
		Platteville			90	Marly shales and limestones
	Canadian	St. Peter			100	Sandstone.
		Lower Magnesian	Shakopee		80	Dolomite.
			New Richmond		20	Sandstone
			Oneota		150	Dolomite.
Cambrian.	Potsdam	St. Croix	Jordan		100	Course sandstone
			St Lawrence		30	Dolomite more or less arenaceous.
			Dresbach		150	Sandstone with beds of glauconite
Archean.	Huronian	Sioux Quartzite			25	Quartzite

— Special Diagram —
Illustrating Devonian Overlap

In places these three formations follow each other conformably but to the northern counties, owing to subsidence, the Dev. overlaps or rested upon Maquoketa

nesian of Owen into three units, here named respectively the Oneota, New Richmond, and Shakopee. In the earlier reports of the Iowa Survey the term "Oneota" was used as the full equivalent of the Lower Magnesian of Owen.

The St. Peter sandstone needs little comment further than to say that McGee, in his *Pleistocene History of Northeastern Iowa*, extended the application of the term downward so as to make it include the Shakopee and New Richmond of the Lower Magnesian stage. It was assumed that the two sandstones are related, and the intervening Shakopee limestone is only an incident. Apart from the fact that they are made of quartz grains, the two sandstones have nothing in common. The New Richmond lies in thin beds; the surface of the beds is often ripple-marked; the individual grains, in the most perfect way imaginable, show secondary enlargement; some parts of the formation have been converted into a fair quality of quartzite. None of these things characterize the St. Peter.

The Platteville and Galena limestones.—The confusion which has arisen in connection with the use of the terms "Trenton" and "Galena" as applied to certain Ordovician limestones of the mid-western states, and the probable causes of such confusion, are discussed in the "Geology of Dubuque County," in Volume X of the *Iowa Geological Reports*. The assemblage of strata covered by the two names conjoined is divided by a persistent band of shale and shaly limestone carrying *Orthis subaequata* and *O. tricenaria* of Conrad as characteristic fossils. This band has been called the "Green Shales" in some Minnesota and Iowa reports. All the beds above the "Green Shales" are dolomitic at Dubuque, and, so far as concerns this locality, they have been consistently known as the Galena limestone ever since the publication of the report on the *Geology of Iowa* by James Hall in 1858. In localities where these beds are unaltered limestones, they have usually been spoken of as Trenton. Lithology, and not stratigraphy, was the basis of the classification. It is now proposed to use the term "Galena" for all the strata above the "Green Shales," whether they are dolomitic, as at Dubuque, or are non-dolomitic, as along the river at and above Decorah. Bain's name, "Platteville," is acceptable for the beds below the top of the "Green Shales."

The Maquoketa shales were so named by White in his report on the *Geology of Iowa*, published in 1870. The beds are, in part only, the equivalent of the Cincinnati shales of Meek and Worthen, of the Hudson River shales of the New York geologists.

The Niagara limestone.—Lithologically, the Niagara series of Iowa is wholly unlike that of New York. There are no sandstones, no shales, practically no unaltered limestones. In the mid-west the Silurian is represented by a great body of dolomite in which there is more or less commingling of the Clinton and Niagara faunas of the region farther east. In some cases a number of life zones may be recognized. *Syringopora tenella* characterizes one of these; *Pentamerus oblongus*, another; another has *Caryocrinus*, *Eucalyptocrinus*, and related forms as diagnostic types; and others, like that carrying *Dinobolus Conradi*, are marked by still different species. But these zones are not well set off one from the other, and in many localities there is more or less of intermingling of forms from adjacent zones. The lower part of the Niagara limestone, including the zones between the base of the formation and the top of the Pentamerus-bearing beds, is quite distinct from the upper portion which includes what have been called the Le Claire and the Anamosa limestones. In the earlier volumes of the current series of *Iowa Reports* the lower phase was designated the Delaware stage, and the upper has been called by Norton the Gower stage. The term "Delaware," however, as the name of a geological unit, was used by Orton for a phase of the Ohio Devonian as early as 1878, and it is proposed in the Winneskiek County report, now in press, to use "Hopkinton" in place of the preoccupied term "Delaware" for the lower phase of the western Niagara. All the characteristics of this stage are well displayed in the quarries and ravines within a radius of two or three miles around Hopkinton in Delaware County, Iowa.

The Devonian system.—The Devonian is represented in Iowa by an assemblage of sediments carrying characteristic Devonian faunas. It is not possible, however, definitely to correlate any part of the western Devonian with any part of the sediments referred to the same system in New York. There is certainly nothing west of the Mississippi which can be said to represent the Helderberg or Oris-

kany of the East, and the New York Corniferous, or Onondago, is but doubtfully indicated by a few species. The faunal relations of our Devonian, so far as it is possible to recognize such relations, are with the divisions generally known as Hamilton and Chemung. The conditions of sedimentation were different in the two areas, mechanical sediments and turbid waters prevailing in one, clear seas and organic deposits characterizing the other; geographically the basins were separate; a very large proportion of the species are quite distinct and are useless for purposes of correlation. Of the species which are common the order in which they arrived in the respective basins is not the same, some of the upper Devonian forms of New York appearing early in Iowa, while some of the earlier ones came late. In a general way, therefore, but not in any way definite or specific, the Middle and Upper Devonian may be recognized; but not even in the most general way can we point to anything corresponding to the Lower Devonian of the New York section. Indeed, the remarkable lung fish, Dipterus, which elsewhere is found only in the Upper Devonian, occurs in Iowa in formations which have been tentatively referred to both the middle and upper divisions of this system. The system has been divided in Iowa on the basis of a marked unconformity; faunally the two divisions are not very distinct. The intimate faunal relations between the Independence shales, near the base of our Devonian, and the Lime Creek shales, above the unconformity near the top, are noted in the reports on Cerro Gordo and Buchanan Counties. The three units referred to the Upper Devonian—the Sweetland Creek shales, Lime Creek shales, and State Quarry limestone—do not lie one above the other, but each is locally developed and lies unconformably on the Cedar Valley limestones.

In Cedar, Linn, and Scott Counties the Devonian follows the Silurian conformably, but in the northern counties, Howard, Winneshiek, and Fayette, there is a record of subsidence due to crustal warping after the Devonian was fairly well advanced, and the rocks of this later system overlap the whole Niagara, and, in the counties named, their eastern edge rests on deeply eroded Maquoketa. An attempt is made to show these relations in the special diagram at the foot of the columnar section sheet.

The Lower Carboniferous-Mississippian.—It is possible, indeed probable, that there is an unconformity between the Devonian and Lower Carboniferous, but it has not been positively demonstrated. The actual contact of Devonian and Kinderhook has not been observed. The faunal break is not exceptionally great. The stromatopores, favosites, and most of the other corals characteristic of the Devonian do not appear in the Kinderhook, and the same is true of the Stropheodontas, Strophonellas, and Atrypas; but the Orthothetes, Rhipidomellas, Spirifers, and Cyrtinas have pronounced Devonian relationships. *Productella pyxidata* and *Ptyctodus calceolus*, collected in the Kinderhook of Missouri, furnish other points of affinity between the Kinderhook and Devonian faunas. On the other hand, leaving out Productella, the Productidae of the Kinderhook are decidedly Carboniferous, and the fish fauna in general points unmistakably in the same direction. The Burlington limestone and the Keokuk limestones of the earlier geologists of Iowa and Illinois have been united under the term "Osage" or "Augusta." While the two alternative names are not quite synonymous, it is probable that geologists will unite on the term "Osage" for the assemblage of limestones, cherts, and shales under consideration. The St. Louis limestone brings the Iowa Mississippian to a close, and this formation remains as originally defined. When the later Mississippian, the Kaskaskia or Chester, was deposited, the shore lines, so far as now known, lay outside the limits of our state. That the greater part of the Mississippian was characterized by comparatively arid climate is supported by many lines of evidence.

The Pennsylvania series includes the productive coal-measures and presents the usual characteristics, biologic and lithologic, of equivalent deposits in other parts of the world. One of the most pronounced unconformities in the Mississippi valley occurs between the Upper Carboniferous and the older formations. When the Pennsylvanian series began, the shore-line was probably as far south as Arkansas. There are indications that, at that time, Iowa stood higher with respect to tide level than it does at present, and deep erosion trenches were cut in the Silurian, Devonian, and Lower Carboniferous formations. When subsidence allowed the sea to return, it advanced upon a scarred and eroded surface, depositing

shales and sandstones of the Des Moines stage in old drainage channels, and over the surface generally, as far to the northeast as Delaware and Jackson Counties. In the counties last named remnants of coal-measure strata are found in troughs cut in Silurian, and even Ordovician, beds, and similar remnants occur in old river channels cut in the Devonian limestones of Muscatine, Linn, and Johnson Counties. The extreme advance of the coal-measure sea was of comparatively short duration. For the greater part of the Des Moines stage, so far as it is represented in Iowa, the shore-line oscillated back and forth over the area now occupied by the valleys of the Des Moines and the Skunk Rivers. Within this area there are records of numerous slight movements of elevation and subsidence.

The sediments referred to the Missourian stage follow those of the Des Moines without break. The crustal oscillations seem to have been less numerous; the waters were clearer; the climate was less humid; arenaceous deposits are scarce; limestones and shales make up the bulk of the deposits of this stage; progress was made toward the more arid conditions of the Permian.

The Permian.—The gypsum beds in Webster County, together with the associated red shales and sandstones, have been referred by Professor Wilder to the Permian system. By some writers they have been referred to the Triassic, by some to the Cretaceous. These beds contain no fossils, and their stratigraphic relations are such as to lend no aid in determining their exact position in the geological column. They lie unconformably on deposits of the Des Moines stage; in some places they rest on St. Louis limestone, for erosion had cut through the whole thickness of the Des Moines sediments before conditions favoring the deposition of gypsum began.

The Cretaceous system.—The Dakota and Colorado stages of the Upper Cretaceous are represented in northwestern Iowa by a series of sandstones, shales, and chalky limestones. In his report on the *Geology of Iowa*, published in 1870, White divides the Iowa Cretaceous into the "Nishnabotany sandstone," the "Woodbury sandstones and shales," and the "Inoceramus beds." The sandstones along the Nishnabotna River, as well as those at Sergeants Bluff and Sioux City in Woodbury County, together with some

interbedded shales, are referable to the Dakota stage; while the main body of shale and the calcareous Inoceramus beds represent the Fort Benton division of the Colorado. It is not certain that there is any true Niobrara in Iowa. During the long interval between the Upper Carboniferous and the Upper Cretaceous the surface of Iowa was deeply eroded, and it was on such a surface that the Cretaceous sediments of the state were unconformably deposited. Since the Cretaceous, these sediments, which were comparatively thin at the most and imperfectly consolidated, have been extensively removed by erosion, and now occur in more or less isolated patches. On the geological map of Iowa the Cretaceous is indicated over the entire area upon which it was originally spread.

The Pleistocene deposits.—Iowa was exceptionally fortunate in its location with reference to the movements and marginal limits of the successive ice-invasions of the Glacial epoch. The state, therefore, offers unusual facilities for the study of the relative age and differential characters of the several sheets of drift which make up the great body of mantle rock within the limits of the glaciated area. The succession of the glacial and interglacial stages which have been recognized by members of the national and state surveys is indicated in the columnar section, and the subject will be found discussed in the national and state reports.

THE DEVONIAN SECTION OF ITHACA, N. Y.[1]

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Ithaca, N. Y.

At a meeting of the American Association for the Advancement of Science, June 29, 1906, the following chart was exhibited before Section E with explanations (an abstract of which is given below), under the title "Revision of the Geological Section Running through Ithaca, N. Y."

REVISED CLASSIFICATION AND NOMENCLATURE OF THE SECTION PASSING THROUGH ITHACA, N. Y.

Series	Formations	Members and Lentils	
Erie Division or Series of Vanuxem	Chemung (shale and sandstone) formation	Fall Creek conglomerate lentil	0–10′
		Wellsburg sandstone member	600–650′
		Cayuta shale member	600′
	Nunda (shale and flagstone) formation	Enfield shale member	550–800′
		Ithaca shale member	80–460′*
		Sherburne flagstone member	188–260′
	Genesee shale formation		125′
	Tully limestone formation		10–30′
	Hamilton shale formation		1035′
	Marcellus shale formation		125′
	Onondago limestone formation		125′
	Oriskany sandstone formation		0–4′

* In the chart as published in *Science* (Vol. XXIV, p. 366) this figure is 300′; see beyond remark on thickness of Ithaca.

ABSTRACT

The accompanying chart expresses the result in classification and nomenclature of the resurvey of the section of the Devonian passing through Cayuga Lake valley and Ithaca, between the Third and Fourth Districts of the original geological survey of the state

[1] Published by permission of the Director of the United States Geological Survey.

of New York made by Messrs. Vanuxem and Hall, and regarded by them as the standard section of the portion of the Devonian there represented. The revision was based upon a critical study of the composition, sequence, and range of the fossil faunas gathered in constructing the folio map of the Watkins and Catatonk quadrangles now in progress. The classification into taxonomic categories (i. e., series, formations, members, and lentils) is in accordance with the rules of classification and nomenclature of the United States Geological Survey as published in the *Twenty-fourth Annual Report* for 1902–3.

The *Nunda (shale and flagstone) formation* is the stratigraphic equivalent of the Portage or Nunda group of Hall, the standard section of which is in the Genesee valley; the term "Portage" having been dropped from the name because it was already specifically applied to the upper sandstone member of the Nunda formation of the Genesee valley. The lithologically discriminated members (Cashaqua, Gardeau, and Portage) there recognized are not distinguishable in the Ithaca section, which is divided into the *Sherburne flagstone*, the *Ithaca shale*, and the *Enfield shale members*. The term "Enfield" is applied to the latter member for the town of Enfield, where its typical exposures are found.

The boundary between the Nunda and Chemung formations is established on the generic change in fossils taking place at the horizon indicated. The more prominent of the new genera first appearing in the Chemung of this section are Dalmanella, Douvillina, and the species *Spirifer disjunctus*.

The *Cayuta shale member* contains the typical Chemung fauna of Chemung Narrows; and the name "Cayuta" is applied for Cayuta Creek along the sides of which, from Cayuta Lake to its discharge into the Susquehanna River, the typical exposures are met with. The upper boundary of the Cayuta member is marked by the fourth (above the Hamilton), and highest at present known, zone of *Tropidoleptus carinatus*, called the *Swartwood Tropidoleptus zone* for its conspicuous outcrop southwest of Swartwood at about 1,600 feet altitude above sea-level.

The second member of the Chemung formation is named the "Wellsburg sandstone member" for its outcrop from Wellsburg

upward into the high hills of Ashland, near the top of which the member is terminated by a thin conglomerate lentil called the *Fall Creek conglomerate lentil.* Immediately below this conglomerate the horizon is indicated by a band of thin-bedded sandstone, often calcareous, containing a great number of shells of *Leptostrophia nervosa* and *Orthothetes chemungensis*, to which the name *Ashland Leptostrophia zone* is applied.

It was noted that the formations of this section, extending from the top of the Onondaga limestone formation to the top of the section, belong to the Erie division of Vanuxem and Hall. This constitutes a natural *series* according to the rules of the Survey; the upper boundary of which, according to the original definition, should be the Catskill division (or series). Although the Wellsburg sandstone member appears to be the upper member of the Chemung formation of this particular section, the author expressed the conviction that the stratigraphic horizon of the Fall Creek conglomerate does not mark the termination, chronologically, of the Chemung fauna.

DISCUSSION

The original definition of the section.—This geological section of the Devonian rocks running through Ithaca was constructed along the boundary line between the Third and Fourth Districts of the state. Lardner Vanuxem wrote the *Final Report on the Third District* (1842), and James Hall the *Final Report on the Fourth District* (1843). The adopted classification and nomenclature of the Paleozoic rocks, up to the base of the Carboniferous, for North America has been constructed on the general lines which were announced chiefly by Vanuxem and Hall, and published in these two reports.

The significance of this particular section was expressed by Vanuxem in his report (1842), in the following passage:

> The Erie division embraces the rocks above those of the Helderberg division, extending to the Catskill group. It presents through several counties on both sides of the boundary of the Third and Fourth Districts two well-defined parts, separated by the Tully limestone and the Genesee slate; these latter are boundary masses of the two parts, being comparatively very thin, and of no great extent of range. The lower part of the division consists of the Marcellus shales and the

Hamilton group; and the upper portion contains the different sandstones and shales below the rocks at Ithaca, subsequently to be mentioned, and the Ithaca and Chemung groups. The distribution of the rocks of the upper part of the Erie division, under the heads of Sherburne flags, Ithaca group, and Chemung group, was founded upon observations made with Mr. Hall, commencing along Cayuga Lake, going south from Ludlowville by Ithaca, and from thence to the Pennsylvania line. The rocks, therefore, along that section, especially the upper ones, are the standard of reference, or types of those of their name. (P. 170.)

From this quotation it is evident that this section was adopted by Vanuxem and Hall as the standard section, and its subdivisions as the standard subdivisions, of that portion of the geological column which was then called the Erie division of the New York system. The nomenclature applied by Vanuxem to this standard section, expressed in tabular form and in natural order of sequence, is as follows:

Catskill division	28 Catskill group
Erie division	27 Chemung group
	26 Ithaca group
	25 Portage or Nunda group
	24 Genesee slate
	23 Tully limestone
	22 Hamilton group
	21 Marcellus shales
Helderberg division	20 Corniferous limestone, etc.

The rocks considered in the present paper are the upper four subdivisions of the Erie division of the New York system.

Original application of the term "member."—The term "member" was used in the text, both by Vanuxem and Hall, to designate a subdivision of a group which offered some local distinguishable characters, but was not regarded as of sufficient importance to incorporate in the nomenclature of the general classification proposed. Thus, in describing the Hamilton group, Vanuxem says: "This group takes its name from the town of Hamilton, in Madison County, which contains no other rocks, and where the best opportunity exists for examining some of the important members of which it is composed;"[1] and Hall, in describing the fossils of the Cashaqua shale, says: "In the Cashaqua shale, or lower member of this group, there are several species of shells which have not been seen in any

[1] *Geology of the Third District*, p. 150.

other rock, and at the same time there are no fossils found in them which are known in other rocks beyond the group."[1]

The taxonomic rank of the original subdivisions of the section.—In geological literature subsequent to the publication of these reports the geographic terms above mentioned have been applied in a technical sense to subdivisions of the geologic column of varying taxonomic value. Thus we find "Chemung group, period, series, beds, and formations;" and in the latest edition of Dana's *Manual of Geology* we find "Hamilton period" described as consisting of the Marcellus and Hamilton epochs (p. 576), and again the "Hamilton group as composed of the Marcellus shale, Goniatite limestone, Hamilton beds, and Tully limestone (p. 593).

Rules of classification and nomenclature.—Confusion of this kind has made it necessary to construct definite rules for nomenclature and classification in which the taxonomic rank of the subdivisions is indicated.

Two well-known examples of such rules are in use. The one was proposed by the Congrès géologique international; the substance of which was published as a report of the *Commission pour l'uniformité de la nomenclature*, made to the Berlin congress in 1885 by M. G. Dewalque, secretary of the commission. The other, as finally perfected, was published in the *Twenty-fourth Annual Report* of the Director of the United States Geological Survey in a passage headed "Nomenclature and Classification for the Geological Atlas of the United States" (pp. 21–27). The first may be said to be the set of rules for the construction of the geologic map of Europe; the second, rules for the construction of the geologic map of the United States.

No attempt will be made in this place to describe either of these sets of rules; suffice here to explain a fundamental difference between the two schemes. Dewalque's scheme was an attempt to unify the nomenclatures of the various nations of Europe by first establishing a set of names to distinguish the order of rank of the divisions to which they were to apply. Thus, to divisions of the first rank (i. e., the largest named divisions of the rock column) the term "group" (French *groupe*) was applied; second, *système* was the

[1] *Geology of the Fourth District*, p. 243.

name proposed for divisions of the second rank (i. e., subdivisions of groups); third, *séries* was the name for the third-rank divisions; fourth, *étage*, for the fourth rank; and, fifth, *assise* for the fifth rank. The terms, *ère*, *période*, *époque*, *âge* were proposed for the time divisions corresponding to the respective stratigraphic divisions of the first list. In this scheme "systems" were the systems in common use. Agreement as to which of the system names should be retained was settled by the congress. Finally it was proposed that all the names of each particular rank should receive the same ending: *-aire*, *-ique*, *-ian;* and thus names show by their endings the rank of the division to which they are applied.

The fundamental difference from all this, seen in the rules of the United States Geological Survey, is the adoption of a cartographic unit and calling it "formation."

The formation the unit in American classification.—In rule 2 it is stated: "In all classes of rocks the cartographic units shall be called 'formations.'"[1] A "sedimentary formation" is defined, viz.: "Each formation shall contain between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character." In other words, the unit division of stratigraphic rocks recognized for mapping, and hence for classification purposes, is a mass exhibiting unity of composition. Provision is made further in the rules for recognizing and mapping "especially developed parts of a varied formation" and calling them members, "*if they have considerable geographic extent*," and and lentils "*if their distribution is more limited.*"[2]

The units of the time scale, however, are, by the United States rules, said to be "periods"—the time equivalent of the standard geologic systems (rules 14 and 15, p. 25), and "for purposes of general correlation formations shall be referred to the standard systems," principally by paleontology. Thus, in classifying and correlating formations with each other, the physical units in the United States are "formations," which may be gathered into aggregates on the basis of correlation of their fossils with standard systems, all of which are in fact represented typically in Europe; but they

[1] *Twenty-third Annual Report*, p. 23.

[2] *Ibid.*, p. 24.

(the formations) are subdivided on the basis of differences in composition locally expressed.

Systems the European units of classification.—In Europe, practically, the "systems" are the primary units found already defined, named and in common use; and subdivisions of the systems are called respectively, according to their order of rank, *séries*, *étages*, and *assises* (these are the French terms).

Terms "group" and "series."—The terms "group" and "series" are also adopted in the United States Geological Survey rules, but they are there used for aggregates of formations, subordinate to systems and determined by local structure rather than simple correlation. Rule 20 sets forth this practice.

> Within the system smaller aggregates of formations may be recognized which shall be called "series," and these may be divided into subordinate groups of formations . . . . These minor aggregates should be formed so as to express the natural relations of the formations of the particular province rather than to conform with divisions recognized elsewhere.

The fundamental difference is exhibited in this rule 20: "Systems" are subdivided in Europe into *séries*, *étages*, *assises;* in America "formations" are aggregated into "groups," "series," and "systems."

In practice American geologists, unless actually working on the survey under the rules of the United States Geological Survey, are more accustomed to adopt the principles of the European rules than those of the United States Geological Survey. This result is perhaps because the European system lends itself better to the use of textbooks and colleges.

Uncertainty as to the definition of "formation."—In the present revision particular attention has been given to meeting the requirements of the rules of the United States Geological Survey. To do so, one of the first, and certainly an important, task required of the investigator is to determine which of the subdivisions of the section proposed by Vanuxem is a "formation" under the rules. Vanuxem realized the nature of the problem when he wrote:

> There are difficulties in the beginning of most, if not all, subjects. Those in the three groups under consideration arise from the little difference in their mineral characters, which, for distant points, cannot be relied upon. The change,

too, in the fossil characters is not so marked as to be at this time available. . . . What has caused geology to advance with rapid strides has been a knowledge of fossils, and when those of the upper part of the Erie division shall have been fully examined, and the kind determined which are limited to a group, and those which are not, then the difficulties will be at an end. (P. 172.)

Vanuxem in 1842 may have estimated too highly the results to be attained by a study of the fossils, but of the nature of the results he had a clear conception.

Neither of the sets of rules above referred to has given an intimation of the way by which we are to distinguish the size (in thickness of strata) of the geological unit, either of classification or for mapping purposes. How thick may a "system" or an *étage* of Dewalque's report be? or, How may a "formation" of the United States rules be distinguished from a "member" or a "group"? The raising of these questions will doubtless call forth scarcely two replies alike. In new work as in the old, the individual is left to draw the limits or boundaries of his "formation" as he will. The literature indicates that usage has been as diverse as is the modern practice.

The fact remains that it is all-important to discover if there may be some means of discriminating between the major and the minor divisions of the geological column.

The taxonomic rank of the subdivisions of the first New York survey.—The specific problem now before us is regarding the rank to be assigned the subdivisions originally recognized by Vanuxem in the Ithaca section.

The Portage or Nunda group.—Vanuxem described the first subdivision above the Genesee (no. 25) as the Portage or Nunda group. It is evident that it is only by correlation that this name is applicable to a part of the Ithaca section. The typical section of the Portage or Nunda group is found in the Genesee valley and is defined in Hall's *Report of the Fourth District.* In that region the "group" is composed of three subdivisions, viz., Cashaqua shales, Gardeau shale and flagstone, and Portage sandstones. It is fair to assume that the taxonomic rank of these subdivisions be tested in the original section, and that the application of the terms to the section at Ithaca rests upon correctly correlating its rocks with those of the original section in the Genesee valley.

Rule 3 of the United States Geological Survey *Rules of Nomenclature and Classification* contains the following provision for discriminating a "formation":

> Lines of separation are drawn at points in the stratigraphic column where lithologic characters change, or where there are breaks in the continuity of sedimentation or other evidence of important geologic events.

In the original definition the line at the base was drawn where the "soft argillaceous rock of a green color" of the Cashaqua shale succeeds the "fissile black shale" of the "Genesee black shale." The upper boundary, although marked by the "thick-bedded sandstones" (Portage sandstones) was distinctly drawn on paleontological evidence. Hall stated:

> Still it must be acknowledged that in lithological characters there is no abrupt change, or evidence of very different conditions in the ocean from which they were deposited, from the termination of the Tully limestone, to the final deposition of the Chemung group (p. 229).

After stating that there are some general differences noted on passing upward by which the Portage and Chemung rocks can be distinguished as masses, he adds:

> When we apply the test of organic remains, we find an equally or even more strongly marked difference in the two groups, and upon this alone a distinction between the two should be made.

Later studies have confirmed both of these points, and upon purely lithologic grounds it would be necessary to go down to the Tully limestone to find a sharply defined lithologic lower limit for the rocks in question. There is no satisfactory upper limit of a purely lithologic nature—not till we reach a definite pebbly conglomerate or a red sandstone such as has been supposed to mark the upper boundary of the Chemung formation. Nevertheless, the rule defines more clearly what is intended by "unity of constitution" by stating that in determining the unity of constitution, which is to characterize a formation, "all available lines of evidence, including paleontology, shall be considered" and "when two formations of closely similar lithologic character are in contact, it will sometimes be necessary to depend almost entirely on the contained fossils in separating them."

These statements distinctly apply to the case in hand. The

unity of the fossil fauna of the three subdivisions of the original Portage or Nunda group, the definite change in faunal composition passing on downward into the Genesee, and that observed on passing upward into the Chemung in the region of the original section, together give ample reasons for regarding this subdivision as a "formation" in the technical sense of the rules. Each of the parts, Cashaqua, Gardeau, and Portage, naturally falls into the nomenclature of "member" as defined in rule 5.

The name of the formation.—There is thus a formation composed of three members already described in the section of the Fourth District of New York to which a definite name was applied by Hall, but to the final adoption of the names of the subdivisions of the Ithaca section rule 7 applies. Rule 7 reads:

> In the application of names to members, formations, and larger aggregates of strata the law of priority shall generally be observed, but a name that has become well established in use shall not be displaced merely on account of priority.

It is well known that the name "Portage" has been largely used for the Portage or Nunda group; there is therefore some question as to the proper name to apply to the formation. Hence, the rule of common-sense must be called into use. Since the rules contemplate the application of distinctive terms to formations, as well as to members and larger aggregates of strata, it is clear that the same geographic part of the name cannot be applied distinctively to two separate subdivisions. The law of priority applies to Portage as the distinctive name for the upper sandstone member of the Portage or Nunda group; this excludes the use of the abbreviation of the group name to Portage by dropping from it the words "or Nunda." It is therefore proposed to rectify the usage by taking the second of the synonymous geographic terms, and omitting "Portage or," from the original name, to leave Nunda as the geographic part of the formation name. Thus the revised nomenclature for Hall's "Portage or Nunda group" is "Nunda formation," composed, in the Genesee section, of the Cashaqua shale, Gardeau flagstone, and Portage sandstone members.

The Nunda formation in the Ithaca section.—A critical examination of the *Final Reports* of the Third and Fourth Districts indicates

that Hall and Vanuxem were not in perfect agreement regarding the correlation of the Genesee and Ithaca sections. Hall evidently believed that the Ithaca group of the annual reports was not distinct from, but a lower portion of, the Chemung group. The equivalent of the Portage or Nunda group according to that view would be found below the Ithaca. Vanuxem, on the other hand, originally intended "to unite the Sherburne and the Ithaca masses, not having discovered in the district those leading characters by which they could be readily distinguished."[1] Both authors evidently expected the fossils, when fully studied, would solve the perplexity.

In the final reports on the paleontology, which was chiefly prepared by Hall, the Ithaca fossils were described as from the Chemung group, thus perpetuating the view held by Hall in 1843.

A review of the section and contained fossils was made by the writer, and published in 1883 as *Bulletin No. 3* of the United States Geological Survey.[2] In that paper it was shown that the fauna of the Sherburne portion of the section below the Ithaca group was present also above the latter; that there are 600 feet or more of strata separating the Ithaca from the base of the Chemung; and that the Ithaca and Chemung faunas are distinct.

The investigations recently undertaken, in preparing the areal map of the Watkins Glen quadrangle, have confirmed the correctness of these points and have demonstrated more clearly the true correlation of the two sections. It has been shown that, upon passing westward from the Ithaca section, the molluscan fauna characteristic of the Nunda formation prevails throughout the whole 1,300 feet of strata following the Genesee shale, with (at the head of Seneca Lake) only a sparse representation of the Ithaca fauna appearing in a few narrow beds in the lower portion of the section. West of Seneca Lake scarce a trace of the Ithaca fauna is discovered, but, when present, it is always below the first appearance of the Chemung fauna. The fauna in the Grimes sandstone of the Naples section reported by Clarke and Luther appears to contain a trace of the Ithaca fauna.[3]

[1] *Report of Third District*, p. 171.

[2] Henry S. Williams, "On the Fossil Faunas of the Upper Devonian along the Meridian of 76° 30′ from Tompkins County, N. Y., to Bradford County, Pa."

[3] New York State Museum, *Bulletin No. 63*, p. 63.

Peculiarities of the formation east of Ithaca.—On passing east of the Ithaca section, into the Dryden and Harford quadrangles, the beginning of the Chemung fauna is found at the same stratigraphic horizon; but the Nunda fauna becomes rare and limited in range in the Enfield member. The upper limit of the Ithaca fauna proper rises higher in the strata, and a successor of the Ithaca fauna appears in the upper portion of the Enfield, below the Nunda Chemung boundary. In the Chenango valley section there is little, if any, trace of the Nunda fauna above the Sherburne sandstone, which there represents, as shown by Prosser,[1] the portion of the Nunda lying below the Ithaca at Ithaca rather than the whole Nunda of the Genesee valley section. In this eastward extension of the portion of the section called "Nunda formation" in the Genesee valley the species of the Nunda fauna are very rarely discovered, but in place of them an increasing number of species of the Hamilton formation appear, mingled with others of the Ithaca fauna.

In these strata there are representatives of three faunas, viz., those typically expressed in the Hamilton, the Nunda, and the Chemung formations. In single sections they appear in the order named; but this order of succession can not be interpreted into an assumption that the time range of each is separate. The faunas undoubtedly lap over in time. In stratigraphy this fact is expressed by saying that the stratigraphic horizon at which one fauna is succeeded by the next in a particular section does not represent the same moment of time at which the like succession occurs in some other section. As has been explained elsewhere,[2] the principle involved is the geographic shifting of two contemporaneous faunas over the same ground. The fact of this gradual replacement of the Nunda fauna on passing eastward by representatives of the Hamilton fauna is indicated in the Ithaca section by the appearance in the midst of the normal faunas lying above the Hamilton formation of thin beds four times repeated, holding a nearly pure Hamilton fauna. Discussion of this subject will be taken up later.

[1] See *Fifteenth Annual Report* of the State (New York) Geologist, pp. 112, 113, 119, 134, and 221.

[2] Henry S. Williams, "Shifting of Faunas, etc.;" *Bulletin of the Geological Society of America*, Vol. XIV (1903), pp. 177–90.

The members of the Nunda formation at Ithaca.—From these facts the conclusion is drawn that the stratigraphic equivalent of the Nunda formation of the Genesee valley is represented in the Ithaca section by three subdivisions or members, viz., *Sherburne flagstone member*, which is the westward extension of Vanuxem's Sherburne flagstones of the Chenango Valley; *Ithaca shale member*, the equivalent of Vanuxem's Ithaca group; and *Enfield shale member*, a member not recognized by Vanuxem or Hall, but first reported by Williams in *Bulletin No. 3* of the United States Geological Survey (p. 30) in 1884 as "Upper Portage." The name "Enfield" is proposed for its outcrop in the town of Enfield, west of Ithaca. The rocks of the Enfield are shales, flags, and thin sandstones as in the Sherburne; the fauna is similar to that of the Sherburne flags below; and the thickness in the Ithaca section is from 600 to 800 feet.

Two reasons may be given for not recognizing the original subdivisions of the Nunda in the Ithaca section. (1) Though the lithologic characters upon which these three members (i. e., Cashaqua, Gardeau, and Portage) were founded become more pronounced going westward, on passing eastward before reaching Ithaca they fail to be distinctive of the lower, middle, and upper portions of the formation. (2) The fauna which was recognized by Hall in 1843 as characteristic of the Cashaqua member prevails throughout the Nunda formation of the Ithaca section. Hence the subdivisions of Hall's original Portage or Nunda group are discarded in the definition of the Ithaca section.

Discrimination of the members.—The Ithaca member is recognized on the basis of its fauna; the portion of the Nunda lying below the Ithaca member is correlated lithologically and stratigraphically with the Sherburne flagstone member of Vanuxem, and the upper portion, lying between the Ithaca member and the base of the Chemung formation, is for the first time given a distinctive name, i. e., the Enfield member. Lithologically and paleontologically the Sherburne flagstone and the Enfield shale or flagstone are very similar; stratigraphically they are separated by the shaly member bearing the characteristic Ithaca fauna. The range of this Ithaca fauna is restricted to a zone of about 80 feet in the Watkins expo-

sure; this range is increased on passing eastward, and at the Ithaca meridian is some 300 feet. The thickness of the Ithaca member, estimating it from the upper Reticularia lævis zone of the Sherburne to the upper Ithaca Reticularia lævis zone is approximately 460 feet at Ithaca.

Lithologic definition of the Nunda formation.—Thus is established a definite stratigraphic subdivision of the Devonian system of formational rank of which the technical name is "Nunda formation," composed of the members Cashaqua, Gardeau, and Portage in its typical outcrop in the Genesee valley, and of the Sherburne, Ithaca, and Enfield members in the Ithaca section.

Lithologically it is defined as an irregular combination of fine fissile shales, either light or dark in color, with, generally, thin-bedded and occasionally thicker beds of sandstone. The shales, in general, are more conspicuous in the lower half; the thicker sandstones are more frequent in the upper part. The light-greenish-colored shales seen in the western part of the state are inconspicuous in the eastern sections. The tough, thin-bedded, often wave-marked sandstone, called "flagstone" from its common use in paving sidewalks, is more frequent in the eastern than in the western outcrops.

THE BLACK SHALE BANDS

The fissile black shales, similar lithologically to the Genesee black shales below, appear throughout the vertical thickness of the formation at various horizons, sometimes of 20 to 50 feet thickness, presenting locally great uniformity. These fissile black shale masses rapidly change their appearance laterally by the intrusion of sandstone bands interrupting the shales, and altering the aspect of exposures to that of the ordinary type of shale and thin-bedded sandstone so characteristic of the whole mass. A typical example of this type of shale is seen at the base of the Ithaca group, near the foot of the hillsides at Ithaca. Locally it seems conspicuous, and I defined and indicated it as the "Ithaca Lingula shales" in the *Bulletin No. 3* of the United States Geological Survey in 1884.

Clarke has defined other local expressions of it under the names *Middlesex black band*, *Rhinestreet black band*, and *Dunkirk black*

band. When the resurvey of the Watkins Glen quadrangle was begun, I expected that these black bands would prove of value in tracing and classifying the rock horizons from one quadrangle to another. It was discovered, however, in the course of the survey, that any particular mass of this fissile black shale does not retain its peculiarities with sufficient uniformity to serve as a reliable mark of a definite horizon.

The same may be said of local thick-bedded sandstones; they are also, so far as thickness is concerned, confined to narrow local distribution. The mode of change in the structure is through a breaking-up of the thick sandstone bed, by increase of shaly bands in its midst, reducing it to a mass of thin-bedded sandstone and shales. When for a considerable thickness no sandstone bands are present, the section appears as a mass of fissile shales; when the shale layers diminish, the sandstone bands run together, and become beds of sandstone separated irregularly by shale bands in which case the sandstones become the conspicuous features in the outcrops.

It was also discovered that the faunas are associated with particular classes of sediments; hence, where similar types of strata appear the fossils are also alike—irrespective of stratigraphic position within the formation through which the same fauna ranges. These are some of the reasons for discarding from the systematic nomenclature all such subdivisions of the strata as are of local narrow distribution.

Subdivisions of the Nunda formation not recognized in the Watkins Glen and Ithaca quadrangles.—Other names have been applied to subdivisions of the formation elsewhere where they are considered to be of member or lentil value. They have been discarded whenever the definitions given them, lithologic or paleontologic, fail to apply to any recognizable portions of the section in the Ithaca region.

According to the United States Geological Survey rules, it has been considered illegitimate to continue to apply member and lentil names to corresponding stratigraphic portions of a formation, when the section ceases to exhibit the lithologic or paleontologic characters upon which discrimination of the members was based. The formation name should be applied, according to rule 4, "as

far as the formation can be traced and identified by means of its lithologic character, its stratigraphic association, and its contained fossils." But the member or lentil is a "specially developed part" of a formation; it is therefore considered inappropriate to apply the member or lentil name in absence of the characters distinguishing it.

For these reasons the terms "West River shale," "Cashaqua shale," "Parrish limestone," "Rhinestreet black shale," "Hatch shale and flags," used by Clarke and Luther,[1] are not deemed appropriate names to apply to portions of the Nunda formation of the Watkins or Ithaca quadrangles, however appropriate they may be for the sections of Canandaigua Lake or in the Genesee Valley.

Paleontological definition of the Nunda.—Paleontologically the Nunda formation is well characterized by the fauna ascribed to it by Hall in the Fourth District report of 1843 (pp. 241–47). The species named by him are (giving the original names): *Fucoides graphica, Fucoides verticalis, Avicula speciosa, Ungulina suborbicularis, Bellerophon expansus, Orthoceras aciculum, Clymenia complanta, Goniatites sinuosus, Pinnopsis acutirostra, Pinnopsis ornatus, Delthyris lævis, Cardium? vetustum, Orthis tenuistriata, Lucina retusa, Nucula lineolata, Astarte sublextilis, Bellerophon striatus* (Bronn, Phillips), *Goniatites bicostatus*, and *Cyathocrinus ornatissimus*. These nineteen species have been more definitely defined and named, and a great number of other species have been added to them since 1843, but they clearly indicate the fauna. There are in Hall's list eight Pelecypoda, two Gastropoda, four Cephalopoda, two Brachiopoda, one Echinodermata, and two of uncertain classification. About 75 per cent. are Mollusca. Later study of the fauna shows the same dominance of this class. The Brachopods are conspicuous by their absence; and it is the dominance of Brachipods in the Ithaca fauna which distinguishes the zone in which they occur as a well-marked member of the formation. Lithologically the Ithaca rocks are not clearly distinguishable from the other rocks of the Nunda formation of this section, though they are paleontologically. This Nunda fauna was definitely recognized

[1] "Geology of the Watkins and Elmira Quadrangle," by John M. Clarke and A. Dana Luther, New York State Museum., *Bulletin No. 81*, 1905.

by me in 1884,[1] and it was then shown to range "through approximately 1300" feet, including the "Ithaca group." It was then spoken of as the *Cardiola speciosa fauna*. In 1886[2] this general fauna was differentiated into the several stages, *Lingula fauna*, characteristic of the black shales; *Cephalopod fauna*, found more frequently in the green shales; and the special *Cardiola speciosa fauna* also occurring in the greenish shales, but often disassociated from the Cephalopods. In 1887[3] these faunal distinctions were more fully elaborated and defined for the Genesee section. In 1885[4] J. M. Clarke described the fauna and flora of the Naples beds of Ontario county, there proposing the term "Naples beds" to include the Cashaqua and Gardeau members of the Portage or Nunda group of Hall; and in 1898 and 1904[5] the fauna was more fully elaborated by him under the name of the "Naples fauna," and its intimate relations to the European Intumescens fauna was also indicated.

ALTERNATION OF DISTINCT FAUNA

In the paper of 1887[6] the Nunda fauna was shown to run up in the strata at Hornellsville high enough to be mingled with species of the distinctive Chemung fauna.[7] This fact of the alternation of the representatives of two distinct faunas in the zone of transition from one fauna to another has been repeatedly observed in later studies. It led me to the necessity of assuming that two faunas normally appearing one above the other in direct succession owe their order of succession to shifting of their local habitat in the same oceanic basin (i. e., marine faunas), rather than to any absolute

[1] *Bulletin No. 3*, U. S. Geological Survey (1884).

[2] "On the Classification of the Upper Devonian," *Proceedings of the American Association for the Advancement of Science*, Vol. XXXIV (1886).

[3] Henry S. Williams, "On the Fossil Faunas of the Upper Devonian–the Genesee Section, New York," *Bulletin No. 41*, U. S. Geological Survey (1887).

[4] John M. Clarke, "On the Higher Devonian Faunas of Ontario County, New York," *Bulletin No. 16*, U. S. Geological Survey (1885).

[5] *Memoir No. 6*, New York State Museum, "Naples Fauna in Western New York," Parts 1 and 2 (1898 and 1904).

[6] *Bulletin No. 41*, U. S. Geological Survey.

[7] *Ibid.*, p. 80.

extinction of one and replacement by the other.[1] On such assumption the correlation of formations by fossils becomes a complex problem, for we cannot say that the last stage of the fauna of one locality occurs at the same stratigraphic horizon as at another locality. The range of this Nunda fauna (i. e., "Cardiola," "Portage," "Naples," "Manticoceras" fauna) has been shown to pass above the Ithaca fauna in the Ithaca section; at Hornellsville it is seen in contact, so to speak, with the Chemung, and traces of it also occur well up in the zone dominated by Chemung fossils. The result is that to be accurate in drawing formation lines on a paleontologic basis there must be recognized a zone of transition of greater or less extent in which either or both faunas may appear. The drawing of formational boundaries on lithologic basis is not more accurate; but the error is more difficult to detect. The actual number of feet thickness assigned to a particular formation in a local section often depends more upon the positiveness of the assumption as to the actual boundary stratum than upon the definiteness of the evidence of the correlation.

The passage from the Nunda fauna to the Ithaca fauna, from Ithaca back to Nunda, and from Nunda to Chemung can generally be detected within passage of a few feet of strata, the chief reason being that the faunas thus brought into direct sequence are different in their generic and, often, class composition. In the Nunda frail-shelled Pelecypods, Gasterpods, Cephalopods, and Arthropods of its lower orders dominate. In the faunas of both the Ithaca and Chemung formations, Brachiopods, Bryozoa, and Lamellibranchs of the Pectinoid type are the conspicuous forms. The assumption is made that this difference between the Nunda fauna and either the Ithaca or Chemung is intimately associated with environmental conditions of their habitats, hence the contrasted faunas are described as heterotopic in relation to each other.

Difficulty in separating the Ithaca from the Chemung fauna.—When the successive faunas are homeotopic, the difficulty of dis-

[1] Henry S. Williams, "Shifting of Faunas as a Problem of Stratigraphic Geology," *Bulletin of the Geological Society of America*, Vol. XIV, pp. 177–90; "The Correlation of Geological Faunas: A Contribution to Devonian Paleontology," and *Bulletin No. 210*, U. S. Geological Survey, (1903).

tinguishing their characteristics is greater. Clarke has recognized this difficulty in saying that

> it is extraordinarily difficult to fix on a division plane between the Ithaca and the overlying Chemung faunas, as the one passes into the other by easy gradation, and we are still somewhat at a loss in determining specific values indicial of the early stages of Chemung time.[1]

This difficulty has been met in the present revision by recognizing the reasons for the difficulty and drawing the lines accordingly. The reason why it is difficult to draw a stratigraphic horizon plane, separating two faunas in which a large part of the genera are identical and many of the species the same, is because of the evident similarity in composition of the two faunas. This similarity, I have assumed, is due to adjustment of the species of the faunas to like conditions of environment, but in different areas of distribution. The fact that the two faunas contain some distinctive species, associated with a second fact that in the New York province at least the one (Chemung) is always found higher in any single section than the other (Ithaca) fauna, together prove that distinguishing characters are of long standing, From this fact it is inferred that the two faunas developed their peculiarities in different areal centers. The differences are like those distinguishing the Arctic from the Florida faunas of the western Atlantic, or the faunas of the east coast of the United States of America from those of the coast of Europe. If these interpretations are correct, two kinds of differences should be capable of discovery, viz.: (1) differences in the evolution of the species of a common race, and (2) differences in the original stock of the two faunas, i. e., survivals of old races which have become extinct in one and have continued to live in the other.

If we attempt to draw the line of boundary between the two faunas, stratigraphically, it is necessary to assume that the later fauna is not the strict genetic successor of the earlier one, in spite of the close similarity in its species. Either barriers have been removed opening to a common basin the waters of separate basins, or general shifting of temperature by currents or by depth has produced such changes of general temperature that the two faunas have been forced

[1] "Naples Fauna of Western New York," New York State Museum, *Memoir No. 6*, Part 2, p. 213 (1903).

to shift their *locus habitans*. One fauna (the Ithaca) has either become partially destroyed or forced to migrate, while the other (Chemung) has entered for the first time into the region where the New York state rocks were being deposited.

In some particular section the change of occupation may take place suddenly so that the last of the Ithaca species will be brought into close contact with the first appearance of the Chemung, but this state of facts cannot be expected without some violent revolution, of which no evidence is here given. In some cases, particularly east of Ithaca, it is difficult to distinguish the passage, but for the reason that there the Ithaca fauna is in a later state of its evolution than at Ithaca, and thus the transition of species between the two homeotopic faunas is less conspicuous. This is due to the fact that such species as are present in both faunas are then in nearly the same stage of evolution; and, second, because the diagnostic species of both faunas are less in evidence where the Chemung fauna immediately follows the later stages of the Ithaca fauna than, farther west, where a long interval of time separated the period of the occupation by the Ithaca from the period of the income of the Chemung fauna.

[*To be continued*]

PANGONG: A GLACIAL LAKE IN THE TIBETAN PLATEAU

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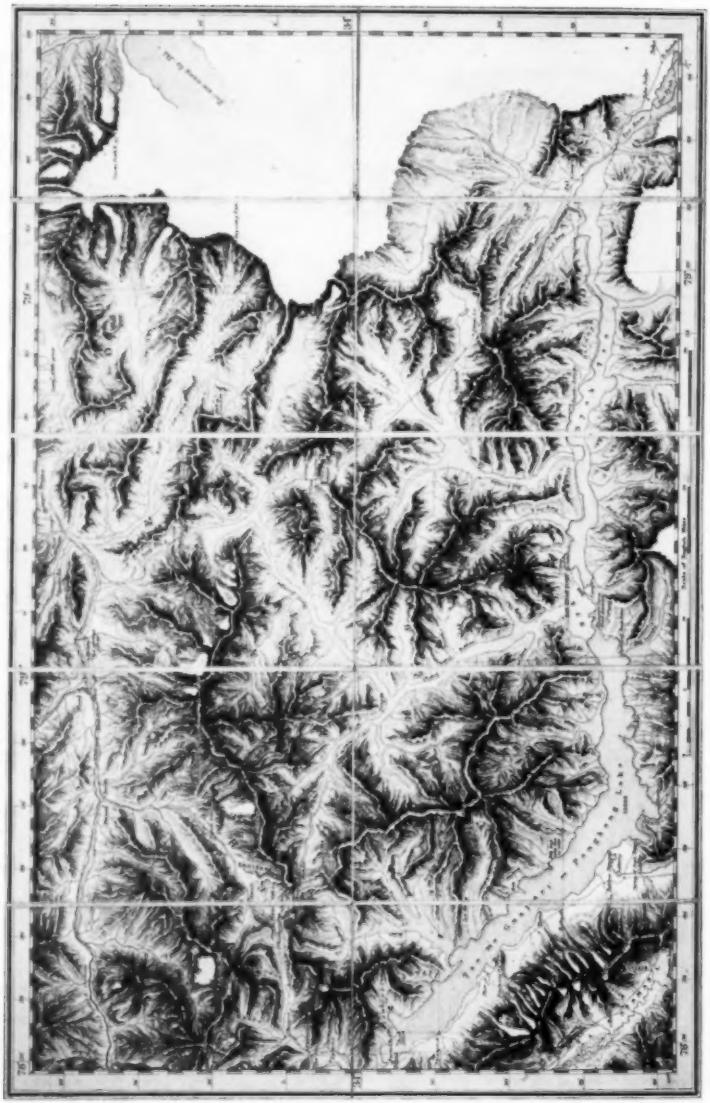
At the western end of Tibet the Tso-mo-gualari, a series of five connected lakes, lies at an elevation of 14,000 feet in a narrow valley winding for over 100 miles from east to west, among magnificent snowy mountains. The upper lakes, which drain from one to the other and are fresh, lie in Tibetan territory and are but imperfectly known; the lowest and largest lake, Pangong, which has no outlet and is saline, lies in the Indian province of Ladakh or Little Tibet, and is visited almost yearly by British sportsmen. As the two main lakes, Pangong and Nyak Tso, with a combined length of 75 miles, and apparently the others also, lie at nearly the same level and are separated from one another only by an alluvial fan or delta like that at Interlaken in Switzerland, the whole series may be regarded as occupying a single basin with a length of 105 miles, a maximum width of 4 miles, and an average width of only 1.8 miles where covered with water. The basin appears to be due to glacial erosion, and the lakes, as their scenery indicates, belong to the same type as the famous valley lakes of Switzerland. Old moraines show that previous to the formation of the present lake the basin was once or twice filled with ice; while lacustrine deposits and elevated beaches show that in later times the lake-level has fluctuated in response to changes of climate less severe than those which caused the invasion of the basin by glaciers. Thus a record of various phases of the glacial period is preserved in a region where it is especially valuable for purposes of comparison.

While on the way to Chinese Turkestan as a member of the Barrett Expedition to central Asia, I visited Pangong, remaining there from May 1 to May 6, 1905. The lake is exquisitely beautiful, a sparkling sheet of the clearest, deepest blue, shading delicately to purple in the shadows and to pure, pearly green in the shallow rim



MAP OF THE TSO-MO-GUALARI LAKES

near shore. Dark, rugged mountains, especially in the eastern part, spring steeply from smiling blue bays to a height of 1,000 or 2,000 feet (Fig. 1, *A*), and then, at gentler angles, rise 3,000 to 4,000 feet more to a chain of peaks, 20,000 feet high, snow-capped and full of glacier tongues (Fig. 2). Verdure alone is needed to make Pangong rival, or even excel, the most famous lakes of Italy or Switzerland.

In early May, at the time of my visit, the snow had disappeared up to a height of 16,000 feet, and two inches which fell at the level of the lake May 6 melted rapidly. The minimum night temperature ranged from 21° to 29° F. The mornings were sunny and warm, but every afternoon between one and three o'clock a strong west or northwest wind arose, chilly and disagreeable, and sometimes accompanied by squalls of sleet. The scanty bushes and still rarer willow trees had not begun to bud, and the few hardy Buddhists of Tibetan stock (Fig. 3) inhabiting the western shores of the lake were just beginning to sow barley, the only crop which will ripen. Sown in the frosts and snow of May, it is reaped in the frosts and snow of September. At the lake level, 14,000 feet, the barley usually ripens, but at Phobrang, a few hundred feet higher, six miles north of the west end of the lake, the crop often fails, and the upper

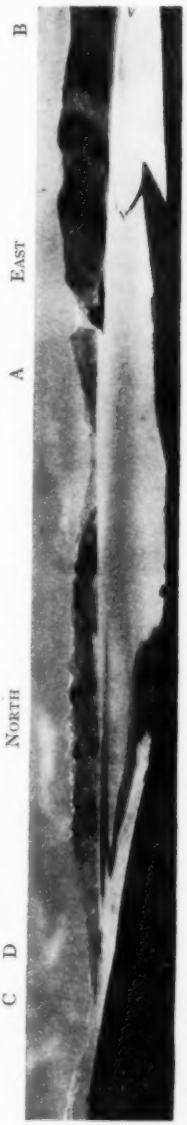


FIG. 1.—Panorama of Lake Pangong from the middle of the south side, May 3, 1905. The west end of the lake had been freed from ice by the wind the previous night, but the narrower and less exposed eastern part remained closed a few days longer.

limit of cultivation is reached not only for this region, but probably for the world.

On May 1 and 2 the lake was entirely covered with pale-green or steel-blue ice, the only exception being some large cracks and a marginal strip 20 to 200 feet wide, where ducks, geese, and gulls fished merrily most of the day, though obliged to sit disconsolate for the first hour or two each morning, when even the open strip was frozen. On the night of May 2 a violent wind blew from the northwest. Next morning, though the temperature was 22° F., the ice had entirely disappeared from the center of the lake for 8 or 10 miles, although the ends were still closed. Part of the ice lay piled along the shore in a ridge 8 or 10 feet high and 30 or 40 wide (Fig. 4). Elsewhere it had been shoved upon the gently sloping beach in large sheets, one of which, from 2 to 4 inches thick, remained unbroken to a size of 15 by 40 feet (Fig. 5). Later I saw a thinner sheet in the act of coming ashore. Un-

FIG. 2.—A little glacier southwest of Lake Pangong, above the village of Man. The latter can be seen on the right lying on an old moraine at the foot of the mountain.

FIG. 3.—A family of Ladakhis living in the outlet valley about 10 miles below Lake Pangong.

der the influence of the usual strong afternoon wind from the northwest, it moved diagonally across the strand at the rate of 3 feet per minute, with as steady a motion as though pushed by an invisible machine. The sandy beach was shoved into a ridge, as appears in the foreground of Fig. 4, and flatstones 8 inches in diameter were easily moved.

FIG. 4.—Ice piled up to a height of 13 feet by the northwest wind on the south shore of Pangong during the night of May 2, 1905. Notice the ridge of gravel shoved up in the foreground.

The quantity of ice thrust upon the beaches did not seem sufficient to account for all of the sudden disappearance. Thinking that a change in the lake's circulation must have been taken place, I resolved to test it by the degree of saltness of the water. On May 1 and 2 I had tasted the latter in the bay east of Mun and elsewhere, and could scarcely detect the least salinity; on May 4 and 5 I tasted it again in the same places, and found it so salt as to be undrinkable. Apparently with the breaking up of the ice under the influence of the wind, currents

FIG. 5.—Ice on the south shore of Pangong, showing sheets 4 inches thick and 40 feet in diameter shoved up entire.

came into play by which a cold film of fresh surface water, due to melting ice, was displaced by warmer, more saline water from below, and thus the remaining ice was quickly melted.

Glacial origin of the basin.—It has been stated by Drew[1] and others that the basin of Pangong is due to the damming of an old outlet by fans from tributary torrents. The old outlet is evident, a broad U-shaped valley extending northwestward from the western end of the lake; and so, too, is the supposed dam, a large fan, 1,500 feet in radius, having its lowest point 90 feet above the lake, and located a mile from the latter at the mouth of a small tributary from the south. The fan forms the divide between the Indus River and Pangong Lake, but it does not appear to have been the cause of the formation of the latter, but rather to have been able to grow up because the

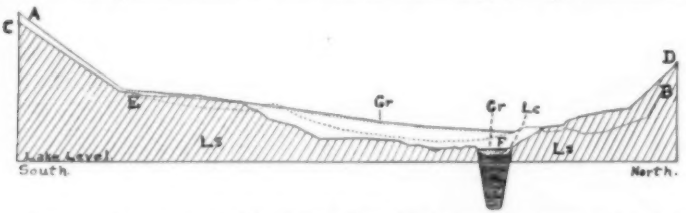


FIG. 6.—Cross-sections of the outlet valley of Lake Pangong drawn to true scale.
A–B=section at the fan, at the divide between Lake Pangong and the Indus.
C–D=section where the rock lip is most plainly visible.
E–F=probable section of the rock below the fan, including a glacial knob.
Gr=gravel.
Lc=lacustrine deposits.
Ls=bed-rock, chiefly marble.

former stream from the Pangong region ceased to flow. The cross-sections of the valley shown in Fig. 6 illustrate the matter. The line *A–B* shows the conditions at the divide, and so far as it alone is concerned, the valley might have been dammed by the fan. The lower section, *C–D*, however, half-way from the divide to the lake, shows quite a different state of affairs. At this point the flat bottom of the broad, steep-sided valley which once served as an outlet is over 600 feet wide; more than 500 feet consists of solid rock, *Ls*, 20 of soft lacrustrine material, *Lc*, and the remaining 90 of gravel, *Gr*, deposited by the insignificant wet-weather tributary flowing from the divide to the lake. Thus the Pangong basin appears to be

[1] F. Drew, *The Jummoo and Kashmir Territories*.

terminated by a rock-lip rising well above the present lake-level. Otherwise there must exist at this point a gorge like that shown in the heavily shaded portion of the section. Its depth must be equal to at least the height of the lowest point of the section above the lake, 35 feet, plus the depth of the lake which Drew (p. 323) gives as 142 feet, that is a total of 177 feet. Its width at the top cannot be over 110 feet. Such a gorge is quite out of harmony with the topography of the outlet valley and of the other valleys of the region, and there is no reason to suppose that it exists.

Furthermore, supposing for the moment that such a gorge existed, it could scarcely have been dammed by the fan of the insignificant little wet-weather stream at the divide. If there were no lake, the outlet stream would be large and swift, for it would consist of (1) the Lamle and Lukung brooks, each of which was large, even in May before the flood season; (2) the stream at Ote from the upper lakes, described by Rawling[1] as a river 60 feet wide and 15 feet deep, with a current of $1\frac{1}{2}$ miles per hour; and (3) a host of minor streams. It is almost safe to say categorically that, even if the climate were drier than now, the floods from the whole Pangong basin, when united into a single stream at the bottom of such an extremely deep, narrow gorge, could not be dammed by the fan of a single tributary, one of the smallest. This is shown by the condition of the old outlet valley below the divide. On either side numerous tributary torrents have formed fans as large as those at the divide; yet even the small wet-weather torrent which here occupies the valley has succeeded in keeping its channel open. To be sure, the stream has been caused to aggrade behind each fan, and at Tso Tsear, 3 miles from the divide, a small lake has actually been formed which overflows with every flood. This, however, is where no water flows permanently and where the drainage area is measured by tens instead of thousands of square miles. Three miles below Tso Tsear, just above Muglib, the permanent stream begins. Though small at first, probably not a tenth as large as the supposed Pangong stream, it has had no difficulty in keeping open a broad channel through fans as large as that at the divide. In view of all the facts, it seems extremely improbable

[1] C. G. Rawling, "Exploration of Western Tibet and Rudok," *Geographical Journal*, Vol. XXV, p. 428.

that there is any narrow inner gorge at the divide, and still more improbable that one of the smallest tributaries, joining the main stream in the gorge where the latter would be most powerful, could completely dam it, especially as the fans of other larger tributaries have produced no such effect. If it be supposed that the outlet has been dammed by a moraine instead of by a fan, it is still necessary to assume the existence of the same improbable gorge, and to explain how such a gorge could ever come to exist. It is further necessary to assume the existence of a completely concealed moraine, for in this part of the outlet valley there is no trace of any such thing, although glacial knobs show that ice once filled it, depositing moraines lower down. The theory of a dam, whether due to a fan or to a moraine, seems untenable. The only alternative is that the Pangong basin is closed by a rock-lip.

FIG. 7.—Glacial knobs in the mouth of the Pangong outlet valley near Tonktse. Glacial smoothing is clearly seen on the left where the fort *A* stands on a completely isolated, well-striated knob.

The most satisfactory explanation of the formation of the lip seems to be that the basin behind it has been glacially eroded. Another possibility is that the lip is due to warping or faulting, but this may be dismissed for lack of evidence. There is no sign of recent faulting in this region, nor of warping of the kind demanded. As is evident from the map, the long, winding basin occupied by Pangong and the other lakes is distinctly a river valley, with no affinity to the type of basin due to crustal movements. Of glacial action, on the other hand, there is abundant evidence, not only near the lake, but down-stream in the outlet valley. Below Tanktse, 20 miles from the lake, an old moraine from 500 to 1,000 feet thick extends 5 miles down-stream. The characteristic topography has been destroyed

and the moraine is smoothed and terraced, but the typical structure remains. Above Tanktse, in the mouth of the outlet valley, finely polished knobs of schist and gneiss (*A*, Fig. 7) show that a glacier came down the valley from Pangong and doubtless deposited part of the moraine, though more may have come from the broader Chumik valley on the south. The knobs and the smoothly glaciated valley bottom are covered in part by a deposit of cobbles and huge bowlders, apparently a moraine laid down in the presence of running water. From analogy with other regions, it is probable that the deposit represents a second advance of the ice, but it may represent merely a stage in the retreat of the first glacier. Farther up the valley, at the tiny lake of Tso Tsear, other glacial knobs appear, and the irregularities in the valley floor shown in the cross-sections of the divide and of the rock-lip in Fig. 6 are of the same sort. It is clear that for 30 miles from Pangong to Dugrukh the outlet valley has been occupied once or twice by glaciers descending below the level of the lake.

FIG. 8.—A deep re-entrant at the northwest end of Lake Pangong. View from an elevation of 1,000 feet looking southeast across the lake at the line of glaciers and moraines on the farther side.

Around the lake itself there are further evidences of glacial action. In the Lukung valley, at the west end of Pangong, a large moraine lies 2 or 3 miles north of the mouth of the outlet valley. Along the southwest shore of the lake something like twenty small glaciers peep out from the tops of the mountains (Figs. 2 and 8), and formerly at times of greater extension deposited moraines well down toward the lake. All these, however, belong to comparatively recent times when, apparently, no moraines reached the basin floor and it was occupied by a lake. The proof of an earlier, more extensive glacia-

tion lies first in the oversteepened lower slopes of the mountains already referred to in describing the appearance of the lake, and second in numerous erratic bowlders of granite perched on slopes and ridges of schist or of metamorphic sedimentary rocks (Fig. 9). The bowlders vary in size from 1 to 25 feet in diameter, and are found at all elevations up to at least 600 feet above the lake. They occur on both sides of the latter, and on almost every slope facing toward it or toward the outlet. The greatest accumulations are found in small protected valleys such as those marked *A*, *B*, and *C* on the map. The granite bowlders can have been brought to their present position on the schist only by a glacier large enough to fill the whole Pangong basin.

The glacier did not come to an end at the rock-lip, as might be expected, but, as we have already seen, continued on for 20 or 30 miles as a comparatively narrow tongue giving rise to the U-shape of the outlet valley, and to the glacial knobs already described, and leaving at least one hanging valley with its mouth 200 feet above the flat valley floor on the south side near the little lake of Tso Tsear. If the Pangong basin is due to glacial erosion, it is necessary to explain why in what once was a single uniform valley the part above the lip has been widened ten times as much as the part below, and deepened correspondingly. Rock structure and texture have something to do with the matter, for there is a hard stratum of marble at the lip; but, except for this, the difference between the schists and metamorphic sedimentaries above and below the lip seem insufficient to account for so marked a contrast. It is possible that the Lukung glacier from the north meeting the Pangong glacier from the southeast acted as a check upon the latter, causing it to broaden and deepen its channel up-stream instead of down. Another possibility is that a glacier or glaciers of smaller size previous to the maximum glacier may have reached only to the lip, broadening the valley above, but not below. When the maximum glacier advanced, the constriction of the valley at the lip would allow only a narrow tongue to extend forward and would cause broadening and deepening of the channel upward.

There is still doubt as to the possibility of the excavation of basins by glaciers. The Pangong basin offers nothing new by which the

question can be answered, but it is significant because it adds another to the examples where a peculiar type of basin is associated with glaciation among lofty mountains. The essential features of the Pangong basin agree with those of the fiords of Norway and the valley lakes of Switzerland and other places. The finding of so perfect an example of the type on the edge of the Tibetan plateau, where the theory of glacial erosion would lead us to expect it, lends probability to the theory. The rarity of such lakes among the Himalayas seems to be due to the fact that most of the valleys slope steeply and uniformly and have no portions of gentle grade where the glaciers would be checked and caused to deepen their beds.

Pangong during later glacial epochs.—The history of Pangong after the completion of the rock basin is recorded chiefly in lacustrine deposits and shore-lines, which, together with numerous old moraines, indicate two extremes of moisture, or at least of lake and glacier expansion intervening between extremes of aridity or of lake and glacier contraction. At the mouth of the little tributary whose fan has been wrongly supposed to be the cause of the accumulation of the waters of Pangong, there are some narrow terraces, remnants of an older, larger fan. The latter must have been formed after the retreat of the last great basin-scouring glacier, and at a time so arid that the main stream was not large enough to carry away the débris brought in by the tributary. If the fan were to be reconstructed from its fragments, it would fill the outlet valley to a depth of 200 feet, more or less; that is, to approximately the level of the highest of the strands presently to be described. As the deposits associated with these strands are saline, it appears that at the time of the accumulation of the fan the lake had no outlet, and hence that the epoch was arid, perhaps as arid as the present.

On the approach of the next glacial epoch the glaciers on the sides of the Pangong basin descended several thousand feet, as is evident from the moraines which they deposited a few hundred or a thousand feet above the lake. The latter must have expanded and finally overflowed, for it cut away the fan across the lip, as may be inferred from the terraced remnants. Before overflowing, however, it must, while still saline, have stood at a level of nearly 200 feet long enough to deposit a thin layer of calcareous

sinter. The latter occurs on an isolated hill of schist east of Tukkung in the middle of the south side of the lake (Fig 9 *A*), and again on a marble spur in the outlet valley close to the lip. It forms a thin coating on the surface of rocks which had been well smoothed and rounded by the previous glaciation. At the same level there are other evidences of the high stand of the lake. In a general view from almost any point a distinct line can be seen at a height of about 200 feet above the present strand wherever the lake shores consist of solid rock, as appears at the right of Fig. 1. In most places it is a mere scratch, indistinguishable close at hand, though visible in a general view; elsewhere it forms a slight notch, or even a very insignificant bench and bluff. Below it, in favorable locations, two or three still fainter lines appear upon the steep rocky shores. The parallelism of the lines to one another and to the present strand, their continuity around the lake, and their utter disregard of the structure of the rocks on which they lie, make it practically certain that they are strands marking former short-lived high levels of the lake.

FIG. 9.—The lower set of beaches in a cove in the middle of the south side of Lake Pangong. The bowlder in the foreground, 12 feet in diameter, consists of granite. It was brought by a glacier to its present position on a slope of schist 200 feet above the lake.

When the lines are followed into some of the minor ravines where erosion proceeds slowly, this conclusion is supported. Here, at a height of about 200 feet, there are a number of little fans hung upon the side of the mountain as though they had been deposited when the water stood much higher than now, and nipped off into terraces in front as though the water had retired step by step. Such terraced fans, like the one at *B* on the extreme right of Fig. 1, may be seen

along the southwest side of the lake on the steep shores between Spangmik and the outlet, on the promontory east of Man, and in the first deep bay east of Tukkung. An allied phenomenon is found in certain well-defined benches contouring around the isolated hills or knobs which lie in the vicinity of Tukkung, and probably represent the line of weak erosion between the main Pangong glacier and the large Lamle tributary. The panorama of the lake (Fig. 1) was taken from one of the knobs which itself is seen in Fig. 9 (*A*) as a flat-topped promontory. In the panorama two knobs may be seen (*C* and *D*), both of which were islands when the lake stood at the higher levels. The benches are best developed on the sides of the farther and larger knob (*C*), which lies about a mile

FIG. 10.—View to the north from an isolated glacier knob near Tukkung, showing the older and the younger set of beaches.

west of the mouth of the Lamle brook. They are cut in the soft, thick talus of the schistose rock, and, as appears in Fig. 10, have clearly the form of strands. In the photograph five benches appear. In reality there are six or possibly seven, lying at subequal intervals between 90 and 210 feet above the lake. Below them, in the right-hand portion of the photograph, still other strands appear, which, however, are much younger and will be considered later. Putting together the evidence of the dissected fan at the outlet, the deposits of sinter up to a height of 200 feet, the faint strand-lines cut in the solid rock, the fragmentary terraced fans, and the benches about the isolated knobs, the history of the lake at this time seems fairly well defined. After the retirement of the last of the basin-making

glaciers a dry epoch ensued, during which a salt lake filled the basin, standing at a low level long enough to allow the accumulation of a fan above the rock-lip. Then, presumably upon the advent of a glacial epoch, the lake rose until at a height of 200 feet above the present level it began to overflow across the fan. From that time onward the water fell, pausing but a short time at each of the levels where the six or seven faint strands appear. One reason for the fall in the lake-level was doubtless the cutting away of the fan at the outlet, but as the latter appears to have been of uniform texture, this will not account for the fluctuations in the rate of fall as indicated by the strands. Another reason was the gradual desiccation which, as is shown below, finally reduced the lake to its last low level previous to that of today. The desiccation probably proceeded at a fluctuating rate, as we shall see to have been the case in a still later epoch, and the terraces and strands may be attributed to this.

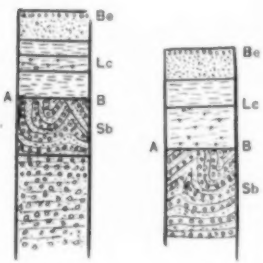


FIG. 11.—Sections of the fan at Tukkung.
A, *B* = Unconformity.
Be = Gravel beach.
Lc = Lacustrine deposits.
Sb = Subaerial (fluvial) deposits.

Evidence of the low level reached by the lake after the formation of the strands just described is found in the present fan at the outlet and in the deposits exposed in cuttings made by streams in other fans along the lake shore. In the outlet valley, as we have already seen, the older fan was cut away during a glacial epoch. The present fan could not have accumulated unless the outlet stream was greatly reduced in size or ceased to flow; that is, unless the climate became somewhat arid. More conclusive evidence of the low strand of the lake is found at Tukkung, along the Lamle brook, where the two sections illustrated in Fig. 11 lie about 100 yards apart, their tops being about 20 feet above the present lake-level. The deposits above the unconformity (*A*–*B*) consist of lacustrine marls, more or less saline, containing fossil shells and plants; while those below are fluviatile deposits of sand and gravel like that which the stream now carries. The folding and crumpling to which the gravels have been subjected is like that which is today produced on

the beach when ice is blown ashore. The lake deposits continue for long distances and clearly belong to the time of the lake's latest expansion. Farther west on the side of a small stream between Man and Meruk the same features are exposed even more clearly in the section of which Fig. 12 is a photograph. The top of the section stands 30 feet above the lake, which lies several hundred

FIG. 12.—Photograph of the bank of a stream near Man, showing features like those of Fig. 11, especially beach gravels broken and tilted by ice and later covered by the deposits of a rising lake.

yards to the right or north of the observer. The succession of strata from the top downward is as follows:

Be	2 feet, fine beach-gravel, and cobbles deposited by the lake in its last	
	4 feet, sandy clay, presumably a shore deposit.	[retreat.
	1 foot, fine gravel, presumably a shore deposit.	
Lc	3 feet, finely banded lacrustine clay.	
	1 foot, white saline marl with lacustrine shells.	
	Unconformity.	
Sb	10 feet, subaerial sands and gravels crumpled by ice.	

Apparently after the fall in the lake indicated by the strands described in the preceding paragraph, the water reached a level so low that subaerial fans were deposited only 20 or 30 feet above the strand of today and possibly still lower. Then the lake rose. At first its ice crumpled the sub-aerial deposits on the lake shore, but

later, as the water rose higher, it planed off their surface and deposited upon them locustrine clays and marls.

If the stream whose banks are illustrated in Fig. 12 be followed upward, a section is found like that shown in Fig. 13, which is typical of the southwest side of the lake. The large moraines (3) belonging to the first glacial epoch after the retreat of the ice from the main Pangong basin form a ridge from 100 to 1,000 feet above the lake. In one of them a valley has been dissected and has been filled with ordinary schistose talus (*T*) from a ridge near by. The talus passes gradually into the subaerial sands and gravels (*Sb*) of the lower parts of the sections described in the preceding paragraph. The next deposit is a layer of lacustrine clays (*Lc*), lying on a smooth, wave-swept surface. On top of all lies a series of beaches (*B*) formed by the lake in the course of its last contraction. Moraine 3

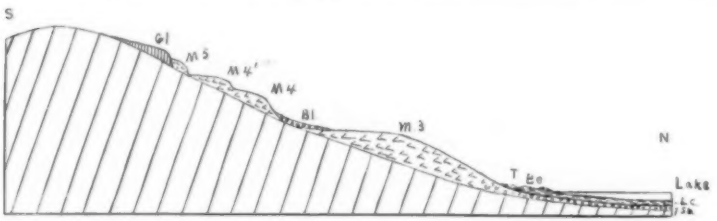


FIG. 13.—Cross-section from Lake Pangong to the summit of the mountains on the south shore of the lake near Man.

Be = Beaches.
Bl = Bowlders.
Gl = Glacier.
Lc = Lacustrine deposits.
M 3, 4, 5 = Moraines.
Sb = Subaerial fluvial deposits.
T = Talus.

appears to be synchronous with the 200-foot lake, and to have been dissected during the succeeding interglacial epoch when the lake stood as low or lower than at present. The moraines 4 and 4′, intermediate in size and age between the present moraine, 5, and the older moraine, 3, are apparently synchronous with the last expansion of the lake, when it rose 60 feet above the present level, crumpling the beach by means of drifting ice and depositing the lacustrine strata *Lc* of the last three sections.

The evidence of this last rise and fall of the lake is very abundant, and has been described by Drew and others. From a height of

60 feet downward the entire lake is bordered by a succession of old strands (see Figs. 9, and 10). The mean levels of the most important strands, as measured in eight sections distributed for 25 miles along the southwest, west, and north shores, were at the following heights above the level of the water in May, 1905, when it was said to be about 3 feet below flood-level: namely, 7, 14, 22, 33, 43, and 61 feet. The strands vary in character in the normal fashion, being marked by beaches in the bays and by cliffs and benches along the headlands. They appear to be of very recent date, this being especially noticeable where they are cut in soft, young fans and are still preserved almost unmarred, even though talus is being poured rapidly upon them. Along the headlands the upper benches are usually cut in a rather hard conglomerate or breccia composed of beach pebbles

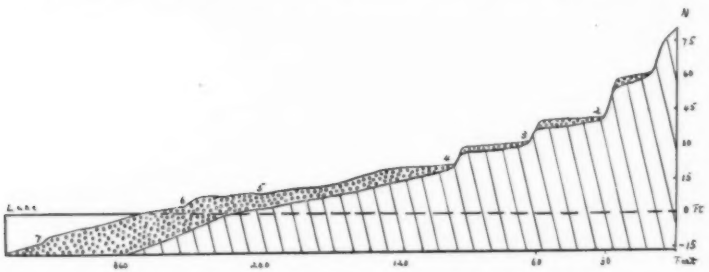


FIG. 14.—Recent lake beaches at the northwest end of Lake Pangong. Drawn to true scale.

and talus cemented by white saline, or calcareous sinter, the deposit of the enlarged lake. In a few especially exposed situations the benches have been cut in solid rock, as illustrated in Fig. 14. The lake seems to have stood longest at the higher levels, since at these it did the greatest amount of cutting. It appears to have had no outlet at any time during its last expansion, for the fan at the lip shows no sign of having been recently dissected (see Fig. 6 *A*, *B*), and its lowest part stands 30 feet above the highest strand. Apparently the fall of the lake and all the accompanying irregularities whereby the beaches were formed are due entirely to desiccation.

Some light on the nature of the process of desiccation may be gained from Fig. 15, which illustrates a section exposed in the same

fan where Figs. 11 and 12 were seen. From below upward along the line *xy* the section is as follows:

A. ½ foot of fine gravel with sand beneath it, the two forming parts of an old subaerial fan or of a beach.

B. 1 foot of lacustrine clay deposited by the lake during its expansion to the 60-foot level and continuing as an uninterrupted band to a height of 50 feet above the lake.

C. 3 feet of shingle deposited on a beach at a time when the lake must have retired.

D. 1 foot of lacustrine clay soon thinning out away from the lake, but thickening toward it and joining *B*.

E. 5 feet of shingle deposited on a beach.

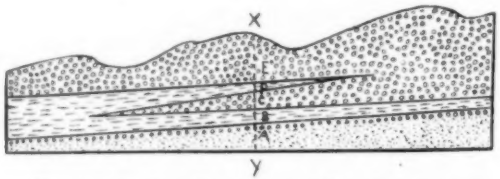


FIG. 15.—Section of lacustrine and shore deposits showing alternating rise and fall of the lake.

The section can be interpreted only on the supposition that in its fall from the 60-foot level the lake fell while *C* was being deposited, remaining at a level of less than 40 feet long enough for the formation of a shingle beach 3 or more feet thick. It then rose 10 feet or more, remaining high until a foot of fine clay had been deposited, and finally fell again, forming the beaches which now lie on the surface. A similar oscillation has occurred still more recently on a smaller scale. At several points along the lake-shore, especially at the northwest corner, three or four little beaches can be seen in the water down to a depth of 12 feet, more or less. The head man of the village of Spangmik said that when he was a boy, some 20 or 30 years ago, the water was 10 or 12 feet lower than now, although in his grandfather's time it stood higher than now. Possibly the submerged beaches, which are very slight, were formed at this time of low water not more than thirty years ago. Whatever their date may be, it is evident that the beaches, like the deposits of Fig. 15, indicate that the lake is subject to constant oscillations due to variations either in rainfall or evaporation. Apparently the process of

desiccation has not been continuous in the fashion illustrated by the line *A*, Fig. 16, nor has it been interrupted merely by periods of rest, as shown in *B*, but rather it has been oscillatory, like *C*, now drier, now wetter, but the tendency to aridity generally greater than its opponent. The changes appear to be of precisely the same nature as the much larger changes which characterize the glacial period with its alternating glacial and interglacial epochs. If the oscillations are merely local, their study is of comparatively small importance; but if, as there is reason to believe, corresponding variations are taking place simultaneously over vast areas, they demand the closest study. There seems to be nothing except size to differentiate them from glacial epochs, and as they are even now in progress, their study can be carried on at close hand, and may perhaps be helpful, not only in solving the secret of the cause of the glacial period, but of the part played by climate throughout the whole course of geological history.

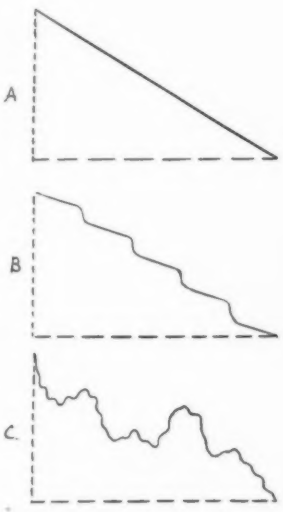


FIG. 16.—Diagram to illustrate the course of dessiccation at Pangong. The horizontal ordinate represents time, and the vertical the condition of climate, wetter or colder upward, drier or warmer downward.

THE DEVONIAN SECTION NEAR ALTOONA, PENNSYLVANIA[1]

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United States Geological Survey, Washington, D. C.

STRATIGRAPHY

Introduction.—This joint article has grown out of work done in connection with the geologic survey of the Ebensburg quadrangle, which is about 5 miles west of Altoona. Fig. 1 shows the location of the section of the state, and Fig. 2 shows in greater detail the area studied and the location of the profile section, Fig. 2. The rocks of the greater part of the Devonian section of the region are very well exposed along the Pennsylvania Railroad west of Altoona, and along the New Portage branch of the same west of Hollidaysburg. They strike about N. 40° E., and dip regularly to the northwest with a uniformly diminishing degree. Only one fault of any consequence is known. It is shown in the profile section, Fig. 2. The downthrow is apparently 100 feet to the east.

In previous surveys of this region it was recognized that the mass of shale and thin sandstones between the Oriskany sandstone below and the bottom of the Catskill above represents the Marcellus, Hamilton, Genesee, Nunda (Portage), and Chemung formations; yet, on account of the generally homogeneous character of the mass as a whole, no effort was made to discriminate and map the individual formations. It has been found possible, however, by taking careful note of the lithologic and paleontologic characters of the rocks, to identify the main formations recognized in New York state, and to establish and map the limits of the same with a fair degree of precision, as will appear in the following description. The section described in this paper then consists of the Oriskany sandstone, the Marcellus shale, the Hamilton formation, the Genesee shale, and the Nunda, Chemung, and Catskill formations. With the exception of the Marcellus, which is not certainly known at Altoona, the above mentioned formations are shown in the profile section, Fig. 2. The section begins at the intersection of Seventeenth Street

[1] Published by Permission of the Director U. S. Geological Survey.

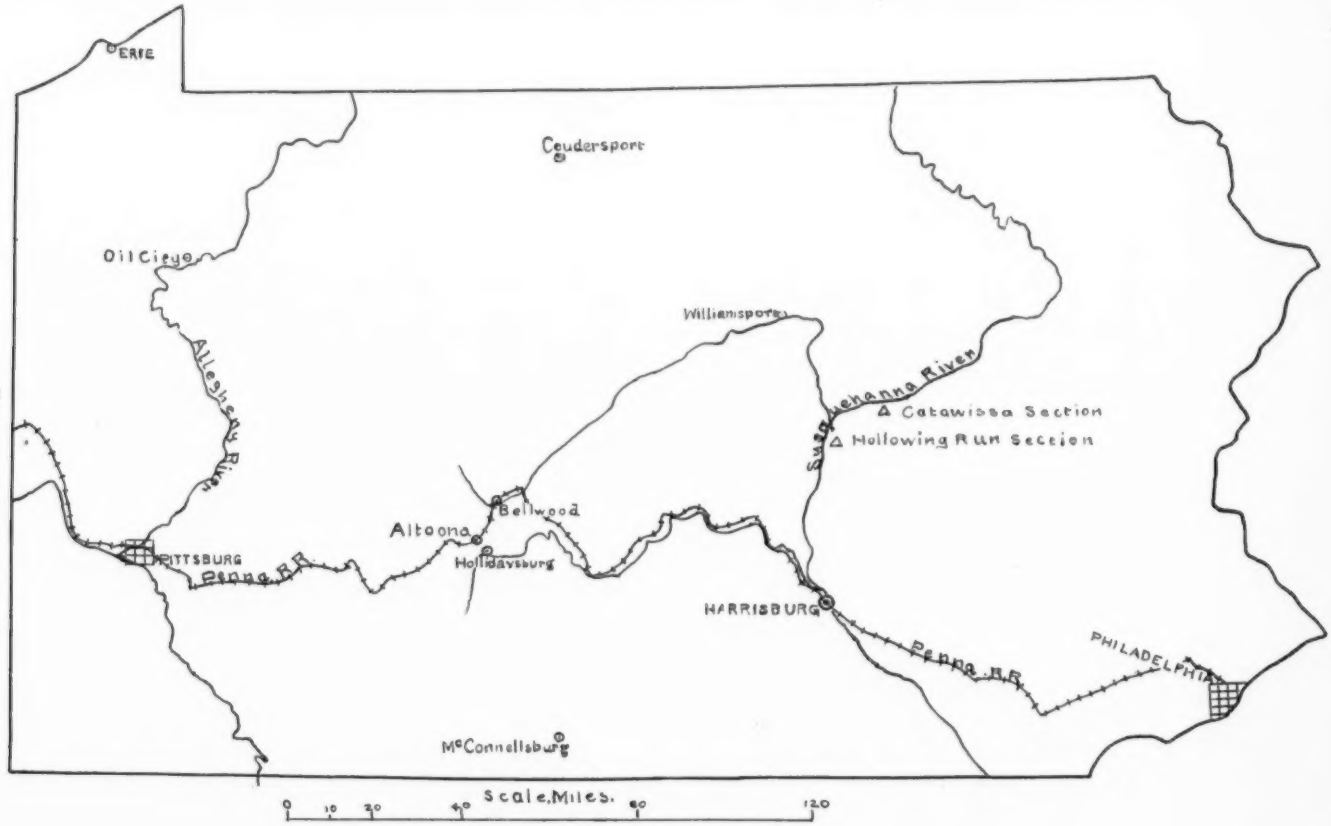

ERIE
Coudersport
Oil City
Williamsport
Allegheny River
Susquehanna River
Catawissa Section
Hollowing Run Section
Bellwood
Altoona
Hollidaysburg
PITTSBURG
Penna. R.R.
HARRISBURG
Penna. R.R.
PHILADELPHIA
McConnellsburg
Scale, Miles.
0
10
20
40
60
120

Fig. 1

and Second Avenue, Altoona, extends thence northwestward to the Pennsylvania Railroad at a point 1,425 feet west of the Logan House and then follows the track to Kittanning Point. (See Fig. 3.) At the base of the section the Lewistown limestone of the Second Geological Survey of Pennsylvania[1] is exposed.

Oriskany sandstone.—This is thick bedded, generally coarse-grained, gray or buff siliceous rock. The thickness seen did not exceed 20 feet, and apparently it is not over 50 feet thick anywhere in the region. Bowlders of this sandstone lie along the Pennsylvania Railroad track about 1 mile southwest of Bellwood, having slid down from the outcrop on the hillside above. From these bowlders the fossils given in the first list on a succeeding page were collected.

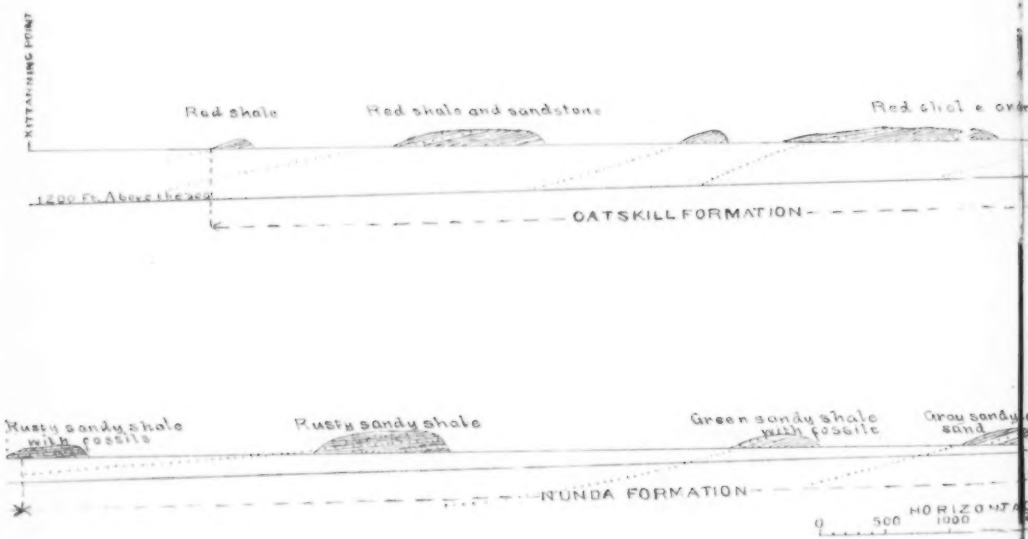
In Altoona an outcrop of Oriskany was observed in an alley just east of Fourteenth Street and between Third and Fourth Avenues. At this outcrop, which is shown on the profile section, the weathered rock is buff, fine-grained, and apparently argillaceous. It contains the fauna of the second list beyond.

At Duncansville, southwest of Altoona, the Oriskany is exposed in a railroad cut and is thick-bedded and siliceous. (See Fig. 4.)

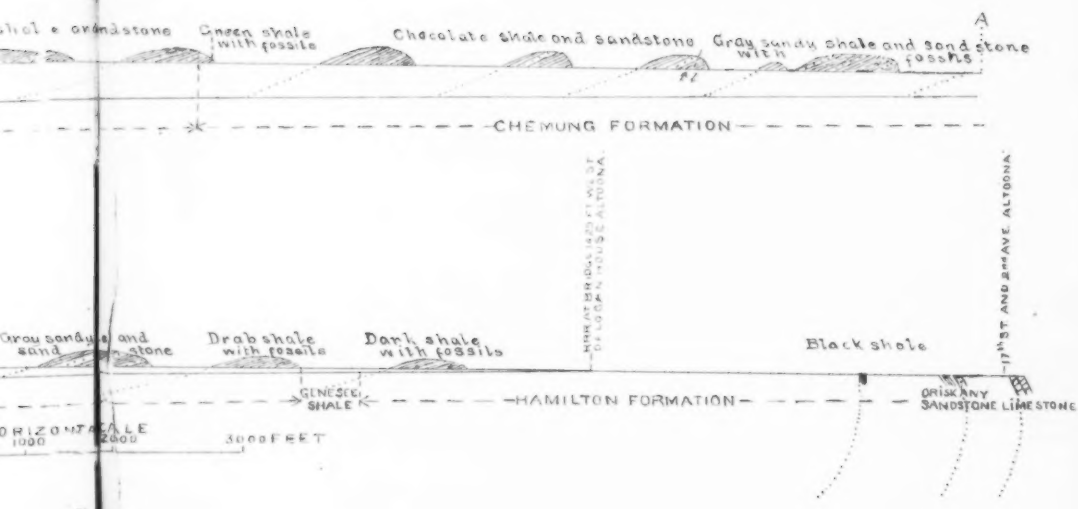
Marcellus shale.—The Marcellus shale follows the Oriskany sandstone directly in this section, the Onondaga limestone of the New York sections being absent as in all of the Allegheny sections south of New York. So far as it can be identified, it is a black, highly fissile, clay shale. It is certainly known only in a railroad cut about 1 mile southwest of Bellwood. At that point about 20 feet of the formation are exposed. Here the Marcellus shale apparently underlies the Oriskany sandstones, since the rocks are overturned and dip to the southeast. In Altoona, shale showing in a thin outcrop on Seventeenth Street near Third Avenue, and dipping 55° to the southeast may be Marcellus, but there is no positive evidence that it is.

Hamilton formation.—The Hamilton formation is predominatingly a very dark green clay shale, which weathers to a dull brown or blackish color, and breaks up in weathering or under the hammer obliquely to the bedding planes into very irregularly shaped pieces. In addition to such rock, there is more or less shale approaching olive-green and gray tints, and also dark green sandy and slightly

[1] Report T on Blair County, by Franklin Pratt.


KITTAPANNING POINT
Red shale
Red shale and sandstone
Red clicl e ove
1200 Ft. Above the sea
OATSKILL FORMATION
Rusty sandy shale with fossils
Rusty sandy shale
Green sandy shale with fossils
Grau sandy sand
NUNDA FORMATION
0
500
1000
HORIZONTA

Fi


Green shale with fossils
Chocolate shale and sandstone
Gray sandy shale and sandstone with fossils
A
CHEMUNG FORMATION
Drab shale with fossils
Dark shale with fossils
Black shale
17TH ST AND 8TH AVE. ALTOONA
GENESEE SHALE
HAMILTON FORMATION
ORISKANY SANDSTONE LIMESTONE
1000
2000
3000 FEET

Fi

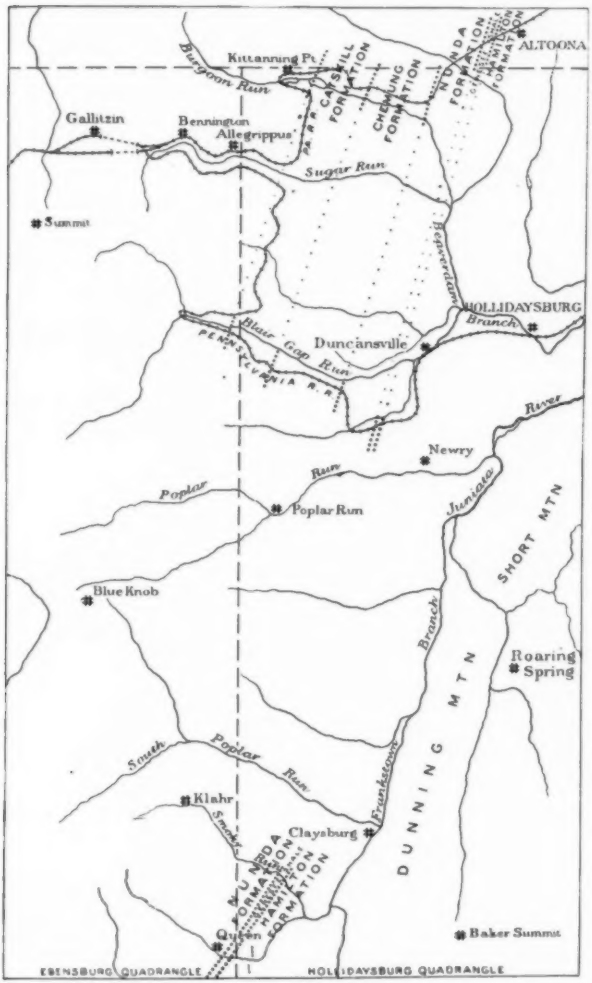


FIG. 3

micaceous shale. Bands of fine-grained, bluish sandstone occur, but they are infrequent and rarely a foot thick. These sandstone layers are often very uniform in thickness, and are divided by joint-

ing into regular prismatic blocks of very characteristic appearance. The bottom of the formation has not been definitely determined in the region; the top is well marked by the Genesee shale, and has been located within narrow limits from the vicinity of Bellwood, on the Pennsylvania Railroad, 6 miles northeast of Altoona, to Queen, about 20 miles southwest of Altoona. In a railroad cut at a point 1 mile southwest of Bellwood, where the present main tracks of the

FIG. 4

Pennsylvania Railroad diverge from the old tracks, the contact between the Hamilton and Genesee is well exposed. The topmost layer of the Hamilton is an impure limestone, 2 to 4 feet thick, crowded with Hamilton fossils, and immediately overlying it is the characteristic black Genesee shale. At Altoona the contact is not exposed, but its position can be closely determined. On the Pennsylvania Railroad track, beginning about 2,375 feet west of the Logan Hotel and just west of the underground crossing of the electric road to Hollidaysburg, is an exposure extending along the track westward for 540 feet, as shown in Fig. 2. Hamilton fossils were found in

these rocks practically to the top. Fig. 5 is a photograph of the shale in this exposure. West of the above-mentioned exposure is a concealed space of 630 feet, to the point where Twenty-first Street intersects the track. At this point is the beginning of an outcrop of rocks bearing a Nunda fanua throughout. At the intersection of Fourteenth Street and Thirteenth Avenue in Altoona the Genesee shale is exposed with overlying shale identical in character and fossils with that at the base of the outcrop beginning on the railroad

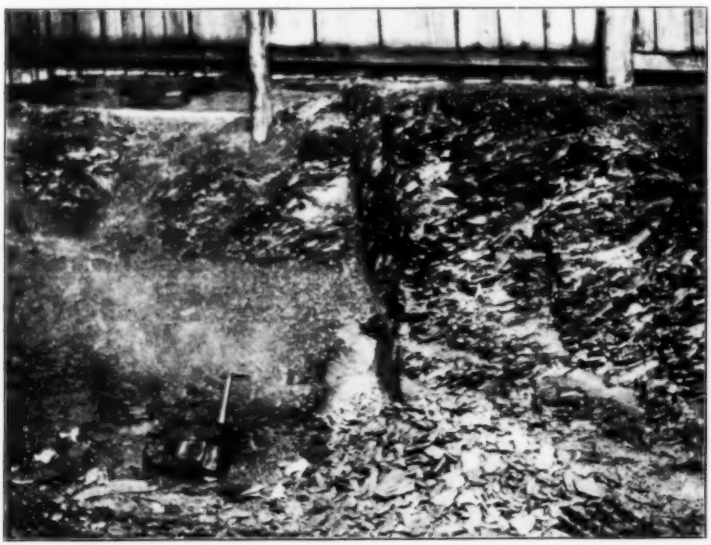


FIG. 5

track at Twenty-first Street, as mentioned above. At the above-described street intersection the Genesee shale is at least 80 feet thick, and the strike of the rocks is such as to carry it through the concealed space along the railroad already described. The thickness of rocks in this space is about 140 feet, and deducting 80 feet leaves 50 feet of Hamilton rocks at the bottom of the concealed space. This would extend the Hamilton formation 230 feet beyond the western end of the first cut west of Altoona Station, so that its top would lie about 2,600 feet west of the Logan Hotel along the track.

On the New Portage Branch of the Pennsylvania Railroad the contact of the Hamilton and Genesee shale can be closely located about 1 mile northwest of Newry, where fragments of limestone full of Hamilton fossils were found at the base of an outcrop of the Genesee black shale. The same contact is well exposed in the road between Claysburg and Queen on the crest of a spur ½ mile northeast of Smoky Run. At this point also a thin, impure limestone with Hamilton fossils occurs at the base of the black shale. The thickness of the Hamilton can be determined only approximately, since in none of the sections studied could the bottom be determined, nor were there a sufficient number of exposures to afford a reliable determination of the average dip. In Altoona the upper part of the formation is exposed, as already described. The dip of this part is 52° to the northwest. At the corner of Fifteenth Street and Sixth Avenue the black shale of the formation was exposed in excavating for the foundation of a schoolhouse. The shale at this point is vertical, as shown on the profile section. It is possible that nearer the bottom of the formation in Altoona the shale is overturned. From the meager date at hand it seems that the average dip of 70° to the northwest would be a probable estimate for the formation, assuming that there are no faults or strong variations of dip. The distance between the Oriskany sandstone in the southeast part of Altoona and the bottom of the Genesee shale at Fourteenth Street and Thirteenth Avenue, described above, is, by the city map, about 3,300 feet, normal to the strike of the rocks. This space is occupied by the Hamilton and Marcellus formations in which the broad Logan Valley has been eroded. Calculating from the width of the outcrop and the assumed dip of 70°, the result is 3,100 feet for the thickness of the Hamilton and Marcellus in the Altoona section.

Genesee shale.—This is a well-defined stratum of black clay shale lying conformably between the Hamilton formation below and the Nunda formation above, and on account of its distinctive character it is important as a horizon-marker in the region. The shale is very fissile, cleaving easily into thin plates and flakes. Its black color is probably due to the presence of carbonaceous matter, as in the type region of western New York. As in the type region, it also contains rather plentiful calcareous concretions. Indeed, the formation pre-

serves to a remarkable degree the characteristics by which it is distinguished in western New York. As already stated in the description of the Hamilton formation, the Genesee shale has been seen between Bellwood and Altoona, at the intersection of Fourteenth Street and Thirteenth Avenue in the latter place, on the New Portage Railroad 1 mile northwest of Newry, on the road midway between Claysburg and Queen, and near Queen. It crosses the Pennsylvania Railroad in the concealed space between a point 2,375 feet west of the Logan Hotel and Twenty-first Street. At the above mentioned street intersection in Altoona a thickness of 80 feet was measured, and, as the base of the shale was apparently not exposed, its thickness may be greater. The upper part of the formation is exposed in the bank of Beaverdam Creek, ¼ mile southeast of Queen, and its full thickness at this point is about 75 feet.

Nunda formation.—This formation has been known in the previous reports on the geology of Pennsylvania as the Portage. According to the usage of the U. S. Geological Survey, however, the term "Portage" should be restricted to the Portage sandstone of the Genesee River section in New York, and the term "Nunda," which was introduced in the early New York reports, applied to the rocks generally designated the Portage group or beds.

The basal 100 or 200 feet of the Nunda formation are composed of soft pale brown clay shale, which weathers to a dove color and has a very perfect cleavage, splitting easily into large, thin, smooth plates. In this shale *Paracadium doris* and *Pterochaenia fragilis* are relatively abundant and come in immediately above the Genesee shale. In passing upward through the formation, the rocks gradually change from the shale above described to a pale greenish-gray sandy shale which makes up the greater part of the formation. This shale generally cleaves easily into thin laminæ, but there are beds of coarser character and less perfect cleavage. Evenly bedded layers of hard, bluish, fine-grained sandstone occur, and some thin irregular layers. These layers are generally from 1 to 6 inches thick, and rarely 1 foot. They are especially abundant through the 100 feet of strata beginning about 350 feet above the base of the formation, and are well exhibited on the Pennsylvania Railroad in the third cut about 1 mile west of the station at Altoona. (See Figs. 6 and 7.)

The peculiar dimpling of the bedding surfaces shown in Fig. 7 is said to be characteristic of the Nunda beds in New York. In the fourth cut, 7,750 feet west of the station, a few bands up to 1 foot thick of compact or shaly, chocolate-colored rock occur, and similar rock is exposed in a cut along the incline No. 10 on the old Portage Railroad. These layers may be the attenuated representatives of the Oneonta phase of sedimentation in eastern New York. The

FIG. 6

thickness of the formation measured along the Pennsylvania Railroad appears to be about 1,400 feet.

In Blair County the bottom of the Nunda formation is sharply marked by the top of the Genesee shale. The top of the formation is, however, very indefinite. No persistent and easily recognized stratum separates the Nunda from the succeeding Chemung formation, nor is there any distinct lithologic change to mark the boundary. The rocks of the one merge into those the other by imperceptible stages. The boundary, as established by the writers, rests on a paleontologic basis. All the beds above the Genesee, and below the horizon at

which the lowest Chemung fossils are found, are here considered to be Nunda. On the Pennsylvania Railroad this point is about 2½ miles west of the Logan House, Altoona, in a cut near the beginning of the curve at which, in going westward, the track turns into the

FIG. 7

valley of Burgoon Run. In this cut is a thin band of sandstone, full of *Leiorhynchus Mesacostale* and *Productella lachrymosa*, or a closely allied form. Under the fossil-bearing band nearly 100 feet of rocks are exposed, but no fossils could be found in them. On the New Portage Railroad the lowest Chemung fossils found were the same

as mentioned above, and these occur in a cut about 1½ miles southwest of Duncansville where the recently constructed branch of the Pennsylvania Railroad diverges from the course of the old Portage Road. (See Fig. 3.) East of this point also are almost continuous exposures of the underlying rock for a thickness of many hundred feet, but no Chemung fossils could be found. No effort was made to trace this boundary farther to the southwest.

Chemung formation.—The Chemung formation follows conform-

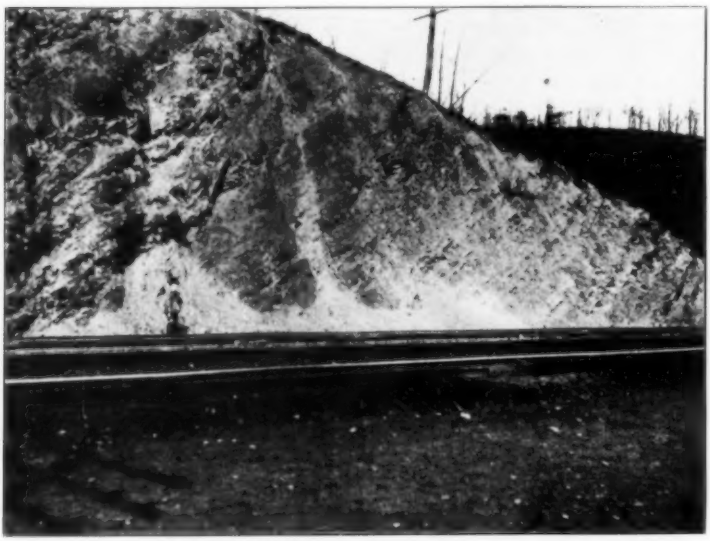


FIG. 8

ably upon the Nunda to which it is, in its lower part, very similar in lithologic character, but from which it is sharply distinguished throughout by paleontologic characteristics. As stated in the description of the railroad section above, the lower limit of this formation is placed at the lowest horizon at which Chemung fossils are found. Its upper limit is the bottom of the distinctly differentiated rocks of the Catskill formation. As shown on the profile section, the formation outcrops for 1 mile along the Pennsylvania Railroad, its bottom being about 2½ miles and its top 3½ miles west of Altoona. Fig. 8

shows the character of the Chemung rocks about 3 miles west of Altoona, and also the fault mentioned on p 624.

The total thickness of this formation in the section just described is over 2,500 feet. In the lower 1,400 feet the rocks are gray or green, sandy or clay shale, with a small proportion of gray sandstone, generally in thin layers in the shale, but occasionally in a stratum 50 feet thick; in the upper 1,000 feet the rocks are charac-

FIG. 9

terized by a large proportion of chocolate shale and by thin layers of chocolate sandstone.

Fossils occur in the topmost layers of the Chemung within a few feet of the bright red shale and sandstone of the Catskill formation.

Catskill formation.—This formation overlies the Chemung conformably. The top of the Catskill cannot be very definitely determined in the railroad section. The red shale shown in the profile section about 1,400 feet east of Kittanning Point probably is not far from the top, since it is apparently followed above by prevailingly gray shale and sandstone of the Pocono formation at the base of the

Carboniferous System. The Catskill formation is about 2,000 feet thick. Probably 80 per cent. of its rocks are red shale and red or brown sandstone, the rest of the formation being gray or green shale or sandstone. The red shale predominates. It is mainly argillaceous and is bright red in outcrop; the red sandstone generally weathers to a gray or dull brown color, and shows its true color only on a newly broken surface. The sandstone is medium- to fine-grained, and may be thick- or thin-bedded or even laminated. It generally occurs in thin layers or strata interbedded with shale, but may occur in thick-bedded strata having a thickness of 50 feet. No fossils were found in the formation, and their absence as well as the red coloration sharply distinguishes it from the Chemung. Fig. 9 is a photograph showing the contact of the Catskill red shale with the overlying Pocono sandstone at the curve about 1 mile south of Kittanning Point, where the Pennsylvania Railroad turns westward into the gorge of Sugar Run. (See Fig. 3.)

FAUNAS OF THE DEVONIAN SECTION NEAR ALTOONA, PA.

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It is the purpose of this paper to present only the more salient faunal features of the section. The data presented are the incidental results of studies and collections made primarily for the elucidation of the areal geology of the region.

The collections on which the faunal lists are based represent only a small fraction of the species which might be obtained by exhaustive collecting. They are sufficiently full, however, to indicate quite clearly the relationship of the several faunas which they represent to those of the standard Devonian section of New York. It is a well-known fact that the Devonian section, as developed in New York suffers great changes, both lithologic and faunal, in the Allegheny region to the southward. But the precise nature of these changes why and where they occur, are not so well known. At present the published data, which can be utilized in the study of the larger problems of Devonian stratigraphic paleontology of the Allegheny region, relate to a very few and widely scattered sections. Until the results of many more carefully studied sections are available, many fundamental questions of stratigraphic paleontology can be answered only hypothetically. The bearing of such local studies on wider problems seems to justify the present paper.

Base of section.—Several hundred feet of gray shaly to heavy-bedded limestones lie at the base of the section which is here described. This portion of the section lay outside of the area under investigation, and no attempt was made to recognize the several members of the New York section which are probably represented.

Oriskany fauna.—A coarse-grained, buff sandstone generally represents the Oriskany horizon. At the east side of the Pennsylvania Railroad, southwest of Bellwood, the Oriskany sandstone contains the following species:

Spirifercumberlandias	a
Rensselaeria sp.	r
Beachi suessana	c
Dalmanella cf. perelegans	r
Gypidula pseudogaleata	r

Southwest of Altoona the Oriskany shows about the same lithologic and faunal characteristics as near Bellwood.

The Oriskany, as seen in the Altoona section in the eastern part of the town of Altoona, represents a facies differing both lithologically and faunally somewhat from the same horizon as it generally appears elsewhere. The rock, which is an extremely fine-grained, soft, buff sandstone, contains one or more species of *Beyrichia* in great abundance. Other common species are the following:

Chonetes sp.	*Pterinopecten sp.*
Anoplotheca dichotoma	*Dalmanites sp.*
Rhipidomella cf. oblata	*Conularia sp.*
Spirifer sp.	

Marcellus fauna.—Only three species have been recognized in the Marcellus shales. These are characteristic Marcellus forms, and are as follows:

Strophalosia truncata	r
Leiorhynchus limitare	a
Styliolina fissurella	a

Exposures which probably represent the Marcellus in excavations in East Altoona yielded no fossils.

Hamilton.—The shales and sandstones of the Hamilton have afforded the following species:

Tropidoleptus carinatus	*Palaeoneilo cf. bellistriata*
Anoplotheca camilla	*Orthonota cf. parvula*
Chonetes scitula	*Grammysia arcuata*
Chonetes vicinus	*Grammysia bisulcata*
Spirifer tullius	*Aviculopecten cf. princeps*
Spirifer mucronatus	*Coleolus aciculum*
Martinia subumbona	*Pleurotomaria sp.*
Stropheodonta perplana	*Phacops rana*
Reticularia fimbriata	

These are all well-known species in the New York Hamilton. *Spirifer tullius* is common in the upper part of the section, and appears to be confined to this portion of the section, as it is reported

to be in the New York sections.[1] *Martinia subumbona* has been observed at only one locality, several miles to the southwest of Altoona. It occurs abundantly in an outcrop in the wagon road about 1 mile northeast of Queen.

The Hamilton appears to be generally less richly fossiliferous than it is in the central New York sections.

Genesee fauna.—The Tully limestone is absent from the section and the dark sandy shales of the Hamilton are followed by the fissile black shale of the Genesee. The Genesee shale of this section is identical in lithologic features with the Genesee of the Finger Lake region. Like the Genesee of the Cayuga Lake section, fossils are very scarce in it. Only two species have been observed. These are:

Styliolina fissurella *Sandbergeroceras sp. undt.*

Nunda fauna.—The Genesee is succeeded by the grayish sandy shales and flags of the Nunda. The fauna which this series of beds has afforded comprises the following species:

Cladochonus sp.	*Buchiola retriostriata*
Palaeoneilo petila	*Ontaria cf. accinta*
Pterochaenia fragilis	*Phragmosoma natator*
Pterochaenia cashaquae	*Probeloceras lutheri*
Paracardium doris	*Styliolina fissurella*
Paracardium delicatulum	*Coleolus aciculum*

This fauna is typical of the Nunda of western New York. All of the species in it are found in the western New York fauna, while none of the forms characteristic of the Ithaca facies occur in it.

During the interval represented by the shales and sandstones of the Nunda two marine faunas, entirely distinct in origin and composition, occupied that portion of the Devonian sea which extended over the present area of central and western New York, central Pennsylvania, and western Maryland. The habitat of these faunas extends southward into Virginia and West Virginia to a point not yet determined. In New York, where these contemporary faunas have been very thoroughly studied, one of them, usually called the Ithaca fauna, is found occupying an area lying in general to the eastward of that held by the other. The eastern fanua was the inshore fauna while the western facies was the more pelagic and proba-

[1] Sixteenth Annual Report, State Geologist of New York, 1898, p. 273; *Bulletin No. 206, U. S. Geological Survey*, p. 47.

bly lived in deeper waters. That the two faunas were limited to their respective areas solely by marine conditions, such as ocean currents, or differences in depth or temperature, is indicated by the frequent interleaving and intermingling of the faunas in sections located near the general boundary between the two faunal provinces. The two Nunda sections nearest the Altoona section which have been studied in Pennsylvania are the Catawissa and Hollowing Run sections, located at the Susquehanna River, to the northeast of Altoona. Comparison of the Nunda faunas of the Susquehanna and the Altoona sections shows that they represent respectively the eastern and western facies of the formation. The dominance of the Ithaca fauna is as complete in the Susquehanna sections[1] as is that of the western fauna in the Altoona section. That the Altoona section is more remote from the old shore-line of the Nunda sea than the Susquehanna sections is indicated by their respective geographic positions as well as by their faunas. The Altoona section is located just at the Allegheny front, while the Susquehanna sections lie well to the southeast of it.

Chemung fauna.—No very sharp line can be drawn on a lithologic basis between the Nunda and the Chemung. The faunas, however, are very distinct, as the following list of the Chemung species indicates:

Orbiculoidea doria
Strophеodonta mucronata
Spirifer disjunctus
Schizophoria striatula
Orthothetes (Schuchertella) chemungensis
Atrypa hystrix
Atrypa reticularis
Delthyris mesacostalis
Dalmanella tioga
Productella lachrymosa
Productella cf. speciosa
Spirifer mesastrialis
Camarotoechia contractavar.
Camarotoechia sappho
Ambocoelia gregaria
Leiorhyncus mesacostale
Strophеodonta cf. demissa
Strohpeodonta perplana var. nervosa
Chonetes scitula
Productella cf. hallana
Leptodesma protextum
Leptodesma lichas
Leptodesma sp.
Pterinea cf. dispanda
Loxonema terebra
Edmondia sp.
Schizodus pauper
Modiomorpha subalata var. chemungensis
Stenaster sp.

[1] The faunas of these sections are listed in *Bulletin No. 244*, U. S. Geological Survey, pp. 78, 91.

This assemblage of species is a representative Chemung fauna, and does not differ notably from the Chemung facies as developed at the type locality on the Chemung River. Like the latter, it includes *Spirifer mesastrialis*, and some other forms which come up from lower horizons, in association with such characteristic Chemung forms as *Spirifer disjunctus*, *Dalmanella tioga*, and *Stropheodonta mucronata*. These three species may be considered pre-eminently characteristic of the Chemung. Their appearance in the sections is coincident with the advent of the Chemung fauna in the Allegheny province, and they remain throughout its stay in the region. In a recent publication[1] it is stated that *Spirifer disjunctus* does not appear in the sections till the "period of Chemung deposition was well-nigh over." The writer, however, has collected this species in one of the sections included in the above-mentioned report, 200 feet below the base of the Chemung, as drawn on the map which accompanies it. It occurs also very near the base of the Chemung fauna to the northeast of the area discussed in the paper. The faunas, therefore, appear very clearly to controvert the statement in question Although *Spirifer disjunctus* is frequently a rare species in the lower part of the Chemung, as it often is in the upper part, the writer's observations indicate that it is generally present at or near the base of the Chemung in some of the sections of any given area, and that the earliest appearance of the Chemung fauna is generally coincident with the advent of *Spirifer disjunctus* southwest of Altoona. In a section near Queen, southwest of the Altoona section, this species occurs near the base of the Chemung. In the Virginia sections it occurs inthe lower Chemung, as it does in New York.

[1] *Bulletin No. 81*, New York State Museum, p. 21.

THE GRAND ERUPTION OF VESUVIUS IN 1906[1]

WILLIAM HERBERT HOBBS

Historical.—From the writings of Plutarch and Strabo we know that previous to the Christian era where now is the complex cone of Vesuvius, with its Atrium and Somma, the latter alone existed, though in the form of a complete ring. This Strabo believed to be a volcanic crater, though extinct. From the time of the earliest Greek colonization no records have been preserved of any eruption in this crater previous to the eventful year of 79 A. D.; though attention has been drawn to the fact that wall-paintings recovered from the buried cities of Pompei and Herculaneum represent the Somma of those days with a somewhat broken wall as though from an eruption. The careful studies of Johnston-Lavis have shown, however, that in the composition and structure of Somma there is the record of no less than fourteen periods of eruption, and of two long intervals of repose not unlike that which immediately preceded the Christian era.[2]

The eruption in the year 79, the greatest of Vesuvius within historic times, was of the explosive type, producing no streams of lava, but supplying such a vast quantity of lapilli and ash that, carried by the *tramontana* then blowing, it was distributed over the cities at the southern base of the mountain and along the slopes of the Sorrentine peninsula. Pompei was covered in places to a depth of 25–30 feet by this material; while the populous city of Herculaneum, situated at the bottom of a steep slope, was overtaken by a flood of mud and ash and buried beneath 60 feet of débris, now augmented by lava streams from later eruptions. The vast quantity of ejected material transferred the coast line from the former port of Pompei to near its present position, reduced the ancient crater

[1] This article was dispatched from Rome a fortnight after the eruption. Various causes have prevented its earlier publication.

[2] H. J. Johnston-Lavis, *Eruptive Phenomena and Geology of Monte Somma and Vesuvius in Explanation of the Great Geological Map of That Volcano* (London, 1891; pp. 21).

of Somma to its present fragmentary form, and laid the foundations of the inner cone—Vesuvius proper. The letters of Pliny the Younger to Tacitus describe the cloud above the crater during this eruption as resembling a great pine (from which the canopy form of the stone pine must be understood), and this simile has ever since served for illustration.

Of the eight eruptions which are recorded between 79 and 1631 we know but little,[1] and the chief interest attaches to the long period of repose which, except for a slight ash eruption (1500), extended over nearly 500 years (1139 to 1631). During this time the crater was forested and overgrown with vines, as it had been for a long time previous to 79; and it is of considerable interest to note that the activity of Vesuvius was in this interim apparently transferred to the Phlegraean Fields west of Naples, where the Solfatara erupted in 1198 and in 1538 a new volcano (Monte Nuovo) formed on the shore of the Lake Lucrinus. Monte Epomeo on the island of Ischia also erupted in 1302.

The greatest Vesuvian eruption of which we have full accounts was that of December 15–19, 1631; which serves as type of the paroxysmal, as does that of 79 for the explosive eruption. This outburst of 1631 began with rumblings within the crater, followed by the opening of a cleft upon the east side of the mountain and the emission of steam and ash. On the following day another fissure opened upon the south side and sent up the characteristic "pine cloud" of steam and ash to overwhelm Nola, Palma, Lauro, and Ottaiano; thus indicating that a southwest wind was blowing as at the time of the present eruption. The climax of this eruption was reached upon the 18th, when lava poured from the crater in four great streams: one of which overran Bosco and Torre Annunziata; a second Torre del Greco; a third Portici and Resina, with the loss of some 3,000 persons; and a fourth Massa di Somma, San Sebastiano, and Sant' Anastasio upon the northwest slope. All streams save the last mentioned precipitated themselves into the sea, where they produced ebullition over a considerable area. It is stated that the cone of Vesuvius was reduced in height by some 170 meters at this time.

[1] The best edited account of these eruptions will be found in the work by Justus Roth, *Der Vesuv und die Umgebung von Neapel* (Berlin, 1857).

The greatest of the subsequent eruptions have occurred in 1737, 1794, and 1822; in all of which outbursts the cone suffered considerable reductions in altitude. In 1855 also it is said to have lost almost 60 meters. In the eruption of 1737 Portici, Resina, and Torre del Greco were all again invaded by lava, as was the latter city in 1794. Of the eruptions which have taken place in 1822, 1839, 1850, 1855, 1861, 1872, 1899, and 1903, much the most important have been those of 1822 and 1872. The last mentioned was of considerable interest because of its rapid development, and because of the favorable conditions which it offered for observing and photographing the mountain. Great quantities of steam were given off; and the lava, which flowed in the direction of San Sebastiano, was typical of the "ropy" surface sometimes assumed by volcanic magmas. In recent years small quantities of lava have for quite long periods oozed from elevated *bocche*.

No volcano has received the same amount of study as Vesuvius, and the greatest amount of accurate knowledge of it has been brought together upon the map of Dr. Johnston-Lavis.[1]

Chronicle of events during the eruption of 1906.—During late September and early October, 1904, Vesuvius was in almost absolute repose. The eruption of lava began May 27, 1905. The charts kept at the Osservatorio Vesuviano to indicate the grade of activity show absolutely no change at the time of the great Calabrian earthquake of 1905 (September 8), the curve of activity for days before and after that disturbance being almost horizontal. In October and November, 1905, lava was dribbling from an outlet high up upon the central cone and near the funicular railway. At night it showed from Naples as a bright red line, which later forked near the Atrio del Cavallo. This stage with the gradual augmentation of activity continued until the first days of April, 1906.

On the 5th of April there was a very decided increase in the violence of the explosions, and an ash cloud mounted high above the crater (see Fig. 6). The climax was reached on the evening of the 7th (Fig. 7), when three earthquakes were felt in Naples of sufficient

[1] Geological map of Monte Somma and Vesuvius constructed by H. J. Johnston-Lavis during the years 1880–88. Scale 1:10,000 (6.33 inches to the mile). In six sheets.

violence to produce considerable panic, but no damage. To this accompaniment of shocks a new mouth or *bocca* opened near the shoulder of the mountain (the *piano*) above Torre Annunziata (see Fig. 1), from which lava issued and descended in the direction of Boscotrecase and Torre Annunziata. Either before, at the same time, or shortly thereafter, two other large streams issued within the same general region and descended the near-lying slopes, the one toward Trecase and the other toward Terzigno. On the morn-

FIG. 1.—Sketch map of Vesuvius and surroundings (areas of lava streams and of lapilli distribution, approximate only).

ing of the 8th the greatest of the lava streams was making its way through Boscotrecase, and before nightfall it had enveloped the city and was on its way down the *vallone* to Torre Annunziata. It came to a halt at the *camposanto* in the outskirts of that city.

Apparently simultaneously with the emission of lava from the new *bocche* a series of violent explosions partly destroyed the central crater, and sent small fragments of lava, lapilli, and ash high into the air, to be carried by a westerly wind over the towns east and

northeast of the mountain. Ottaiano, San Giuseppe and Somma, which hug the northeastern and eastern base of the volcano, suffered most, being in part buried under some three feet of ejectamenta. Nola and Terzigno also suffered heavily, while a leaden sky and a fall of fine cinder were almost universal throughout a fan-shaped area extending at least to the Adriatic and roughly limited to the north by Campobasso and to the south by Avellino and Bari (see Fig. 2).

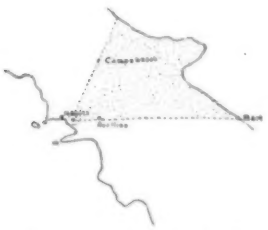


FIG. 2.—Sketch map to show the distribution of lapilli and ash from the principal explosions of the eruption.

The principal loss of life was in San Giuseppe, where in their terror the people crowded into the little church to prostrate themselves before the altar, just before the roof fell from the burden of ash upon it. Many others of the weak house-roofs of heavy tiling (wholly unfitted for such a neighborhood) also collapsed, and in some cases with resultant loss of life. The Circumvesuvian Railway and the line from Naples to Salerno were blocked by the accumulation of ash; though upon the last-mentioned traffic was resumed within twenty-four hours. With the outflow of the great lava streams the violence of the explosions within the crater began to wane (see Fig. 8).

Conditions in Naples.—The shifting winds carried the later and finer ash-fall for much of the time in the direction of Naples. On the morning of the 11th trains entered Naples from Caserta through a cloud so dense that the impression of a tunnel was produced, though the sun was high in an otherwise clear sky. On this day workmen were dismissed from the shops along the water front on account of the darkness; and business in the city, already almost paralyzed, practically ceased through the closing of the shops along the main streets. The exodus of the great body of tourists had been accomplished largely on the 8th, though with much confusion and a greatly augmented train service, the result being that on the following morning many of the grand hotels dismissed their servants. Large bodies of troops, increased by levies from other cities, armed with shovels, were promptly sent to all the afflicted

cities east of the mountain, and with fire companies, *carabinieri*, and the numerous refugees did excellent work in rescuing the wounded and in digging out the railway. Artillery wagons loaded with bread supplied the homeless who still remained in the partly buried cities. By the 15th railway communications had been established between Naples and Ottaiano.

In Naples the roof of the market of Monte Oliveto and a few other poorly constructed houses collapsed from the weight of ash,

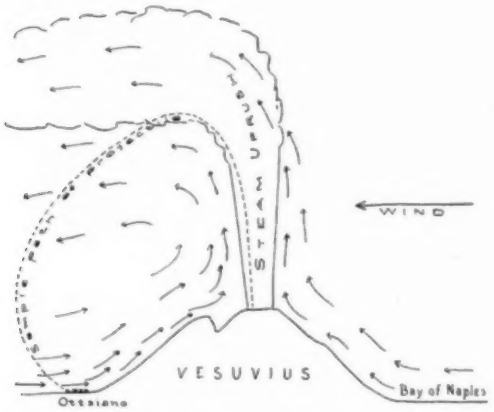


FIG. 3.—Diagram to illustrate the courses of air currents and of projectiles near Vesuvius during the grand stage of the recent eruption.

in the first mentioned instance with considerable loss of life. The principal inconvenience to the people from the falling cinder was to the eyes, which had to be protected with glasses, celluloid plates, or some other device; and of people of the better class upon the streets the greater number carried extended umbrellas for better protection. For a number of days, and until a shifting wind again brought the bright sunlight, the streets were occupied by religious processions following effigies or pictures of San Gennaro, the patron of the city.

In contrast with the eruption of 1872, the late outburst offered little opportunity for observing its developments. The constantly shifting light winds kept Naples and nearly the whole western and northern circumvesuvian country shrouded in ash for most of the

time; and no such excellent photographs as were taken in 1872 appear to have been secured.

FIG. 4.—View of Vesuvius from the south, before the eruption of 1906.

FIG. 5.—View of Vesuvius from the west, before the eruption of 1906.

The electrical phenomena.—An English acquaintance, in whose statements the writer reposes confidence, reported to him that on the morning of the 8th, when the large lava stream was overrunning Boscotrecase, he followed the margin of the stream a considerable distance in the direction of the crater. Almost continuous flashes of lightning seemed to pass from the overhanging cloud nearly straight downward toward the lava; and, if appearances were to be relied upon, at no great distance.[1] On the 15th, when the writer attempted to reach the new *bocca* by following up the stream of lava from Boscotrecase, changes in the direction of the wind left him for considerable periods enveloped in the ash cloud with surrounding darkness too great for following the bad footing over the scoriaceous surface, thus necessitating long delays. At elevations in excess of 1,400 feet above Torre Annunziata heavy rumblings were heard at intervals of from six to nine minutes, and in apparent correspondence with the rhythmic uprush of steam and ash from the main crater. Before the envelopment by the ash cloud the direction of the crater had been ascertained to be in close correspondence with the steepest slopes. The *boati* always began in this direction as low continuous rumblings, like the rolling of heavy wagons over hard and irregular pavements; but they soon moved away to the southward and were transformed into reverberating crashes of thunder so resembling those of a heavy electrical storm as to be unmistakable. In a favorable shift of the wind an altitude of 2,200 feet was reached, when a quick change again brought the black ash cloud and a patter of lapilli, so that further progress (now wholly over fresh lava) was impracticable.

Pliny mentions that in 79 almost incessant lightning flashes accompanied the eruption. The rhythmic *boati* of Vulcano during its great eruption of 1888–89 lacked these striking electrical features, at least at the time the volcano was visited by the writer in April, 1889; and apparently a smaller proportion of water vapor was characteristic of the eruption. Professor Palmieri, the former director of the Vesuvian Observatory, gave careful study through many years to the electrical phenomena attending Vesuvian eruptions,

[1] A friend who was in Pompeii during the great outburst of the 7th has emphasized the grandeur of the electrical phenomena.

including the important one of 1872.[1] By putting up a conductor in the ascending current of steam he was able experimentally to show

FIG. 6.—View of Vesuvius during the eruption of 1906 (earlier stages). Stage of April 5.

Fig. 7.—View of Vesuvius during the eruption of 1906 (earlier stages). Later than Fig. 6, probably on April 7.

[1] Luigi Palmieri, *Elettricità negl' incendi vesuviani, studiata dal 1885 fin' ora con appositi instrumenti. Lo spettatore del Vesuvio e dei Campi Flegrei.* (Naples, 1887; pp. 77–79.)

that the steam as it is condensed by expansion to water vapor becomes positively electrified. Many samples of the Vesuvian *sabbia* from different localities when washed and heated were found to become negatively electrified. He thus found an experimental explanation for the origin of the atmospheric electricity developed during eruptions.

Disturbances of the sea.—On the 5th of April, when the violent stage of the eruption may be said to have commenced, the Bay of Naples is said to have been in unusual agitation, without apparent explanation of the weather conditions of that or earlier days. On the 6th a tidal wave struck the "Barbarossa" one day out from New York en route to Naples. It seems unlikely that either of these phenomena was directly the result of disturbances within the crater of Vesuvius, and it is far more probable that they were attributable to a more or less distant seaquake, which we may be able to locate when the next report of the seismological stations co-ordinated under the British Association has been issued. The time of the Vesuvian eruption falls so nearly in coincidence with the earthquakes of California, Hawaii, and Formosa that relationships of tidal disturbances are otherwise difficult to trace.

FIG. 8.—View of the "Pine Cloud" over Vesuvius on April 11. View taken from Ponte della Gatta looking over the ancient *bocca* of Camaldali della Torre.

Increased activity of the fumaroles in the Solfatara.—It was reported that the fumaroles of the Solfatara showed increased activity during the eruptive phase of Vesuvius. Having last visited them in October, 1905, the writer was able to confirm this by a visit made on April 16 during the closing stages of the main eruption. The vapors which issued from the main fumarole on the later date rushed up with a hissing sound, and in a volume which resembled that from the escape-valve of a locomotive. The services of the attendant, who had been accustomed to stimulate the fumarole with torches, had become unnecessary, and he had deserted his post.

FIG. 9.—View of the main lava stream of 1906. Above Boscotrecase.

The lava streams.—Three large and several smaller lava streams issued from Vesuvius during the recent eruption. The one which caused the greatest damage appears to have been the largest, and flowed from a *bocca* near the *piano* above Torre Annunziata to the cemetery on the outskirts of that city, completely enveloping the city of Boscotrecase and burying it to a roughly estimated average depth of 12 feet (see Figs. 9–12). Above an altitude of about 2,200 feet and almost immediately above the corner monument of Torre del Greco (see Fig. 1), this stream sent off a branch to the westward, which branch, following the course of a diverging *vallone*, was again reunited to the main stream near the altitude of 1,500 feet. The

bocca of this principal stream is above the monument referred to and probably near the *piano*.

A second large stream, which probably issued from a *bocca* somewhat farther to the west, passed over vineyards and isolated houses, and descended to a point near Trecase and only 670 feet (vertically) above Torre Annunziata in a direction a little west of north (see Fig. 1). Fig. 14 shows where this stream had passed through a grove of small stone pines, some of which it broke off and carried along. The several smaller streams were all higher up upon the

FIG. 10.—View of the main lava stream of 1906. In the *vallone* below Boscotrecase. (The lava filled the valley with arching upper crust which collapsed after outflow of lava beneath.)

slopes and in the vicinity of this one. They could be distinctly followed by the eye from the high point reached on the 15th.

The third large stream the writer has not personally followed, but it was reported to him by Professor Sabatini to extend in a direction parallel to and north of the narrow stream of Caposecchi (1834) and to end near Terzigno.

The streams personally examined presented a black scoriaceous surface made up of blocks irregular in shape and generally quite separate from each other, varying in size from a man's fist to great

angular pieces too heavy for a man to lift. The destruction wrought by lava to structures began by the damming back of the stream

FIGS. 11 and 12.—Views of the lava over Boscotrecase with partly buried villas projecting. (Taken April 11, 1906.)

until the structures were fractured and toppled over from the pressure exerted against them. Trees situated near but within the edge of

the stream were surrounded and remained standing. Farther within the margin, however, where the developed stresses were

FIG. 13.—View of the cone of Vesuvius on April 13, from the roof of a deserted villa above Resina. The flat dome is in contrast with the earlier pointed form.

FIG. 14.—View of the surface of the western lava stream above Trecase, where it has overrun a group of pines. (Taken on April 15.)

greater, they were snapped off and carried along upon the surface as passengers. Little if any burning resulted, though the snapped stems were sometimes found charred near the fractured surface. This immunity of inflammable objects from combustion when in contact with lava is apt to cause surprise, though simply enough explained by the insulating nature of the non-conducting lava crust.

The ejectamenta.—The events of the eruption have been so enlarged upon by the fertile imagination of an excited press that the figures given below will doubtless seem to be underestimates. Yet, while it has seldom been practicable to carry out actual measurements, owing to the irregularities of distribution, and in the deeper layers because of the necessity of extensive excavation, it is confidently believed that the figures given are generally within 15 per cent. of the true averages.

The ejectamenta may be roughly classified into lava fragments, lapilli, and ash. The lava fragments and lapilli, if we except the area above the atrium and hence near to the crater, have been restricted in their distribution to the area northeast of the mountain (see Fig. 1), whither they were carried by the wind on the 7th and 8th, during the climax of the outburst. In the belt of cities encircling the mountain lapilli begin to be observed near Somma, and farther east are found almost throughout the thick deposit. Their southern limit, probably near Terzigno, has not been sought by the writer.

Section of the deposits.—The total maximum thickness of the deposits at Ottaiano and San Giuseppe may slightly exceed three feet. The deposits consist of a lower layer, a few inches in thickness, made up of black scoriaceous lava fragments, the largest of which are an inch or more in diameter (in the press reports red-hot blocks weighing 200 kilos descended upon the town). This layer is succeeded by gray lapilli mixed with ash, the former decreasing in size more or less uniformly toward the top. The uppermost inch of the deposit shows in great perfection the succession of colors characteristic of the closing stages of an eruption. The dull gray which succeeds the black lower layer, and which constitutes the major portion of the deposits, here changes into the penultimate thin red layer, the *sabbia rossa*, which was falling upon the 11th and 12th.

Upon this is the surface layer of nearly white impalpable ash. Von Buch, who observed the quite important Vesuvian eruption of 1794, has given the order of colors, which, he states, was then recognized as characteristic, to be black, bright gray, and white.[1] The falling of the *sabbia rossa* during the late eruption was joyously hailed by the Neapolitans as the beginning of the end.

This red ash is probably of the same general characters as the gray underlying material, save for its finer state of subdivision and the greater oxidation of the contained iron. Its fall appears to indicate that, having been long suspended in the higher layers of the vaporous atmosphere above the crater, the diminution in violence of the uprushing steam has left it without support and allowed it to settle. The ultimate layer of nearly white material appears to be still more finely divided.

Effect of the projectiles upon windows.—The windows of Ottaiano and San Giuseppe afford material for an interesting study. On the sides of houses opposite the mountain they were broken in apparently much more generally than on the side facing it, and even when protected from falling blocks by deeply set casings. In several of the windows specially examined possibility of reflexion from neighboring walls was excluded, and in all cases rather improbable. Sometimes almost entirely broken out, in other instances they presented only a few cleanly cut holes almost perfectly circular in form, and generally between two and three inches in diameter. These holes were wholly devoid of radial fractures. Sometimes two or more holes overlapped, but always with the same cleanly cut outlines. In a number of cases the circular crack appeared, but with the inclosed disk still in its place to indicate that the missile had rebounded. The holes are clearly much larger than the flying missiles which produced them. The large amount of ash in the air at the time of the writer's visit to these cities made photographing difficult, and the exposures from these windows were unfortunately failures.

The explanation of these fractured windows on the sides of buildings away from the volcano is probably to be found in the inrush of air from all sides toward the crater to replace that removed by

[1] L. v. Buch, *Gesammelte Schriften*, Vol. I, pp. 397–404.

the great uprush of the steam. In times of grand eruption Vesuvius becomes a gigantic steam injector (see Fig. 3). As already stated, the light wind blew at the time of the grand paroxysm from the southwest, or over the crater toward Ottaiano. On the side toward the bay the force of this current would simply be increased, whereas on the Ottaiano side the southwest wind would be replaced near the surface by a contrary current blowing in the direction of the crater. From the fact that lapilli even are not found west of the crater at points below the *piano*, it is clear that projectiles which fell at Ottaiano must have followed a course determined largely by air currents, and presumably similar to that indicated in the diagram. That they reached the ground in directions inclined at fairly flat angles in the direction of the volcano would appear to follow from the damage done to the upper portion of windows protected by casings nearly or quite a foot in depth.

The ash layer to the north and west.—To the west of Somma, and along the shores of the bay only ash is found. Its depth may reach six inches between Portici and Torre del Greco, though elsewhere it is generally considerably less. Higher up on the slopes its thickness increases until at the observatory it attains a thickness of perhaps ten inches, and with it are associated extremely fine lapilli.

In Naples the depth of the ash deposit hardly exceeded an inch, certainly not an inch and a half. The collapse of the roof of the market of Monte Oliveto, and of a few other buildings in Naples, is adequately explained by the high specific gravity of the ash and the weak construction of the buildings. The agriculture of all this northwestern, western, and southern belt will quickly recover from the loss which it has sustained. As regards Somma, Ottaiano, San Giuseppe, and to a less extent the more distant cities to the northeast of the mountain, a considerable time must probably elapse before the soil will again become productive.

The truncation of the cone.—It is impossible at this writing to give accurate figures concerning the reduction in height of Vesuvius; but that the cone has been reduced to near the level of the Punta del Nasone, the highest point of Somma, appears from views of the mountain.[1] It was reported in the newspapers, upon the

[1] Such data are illusory and later measurements show the truncation to have been much less.

authority of the director of the Vesuvian Observatory, that this truncation amounts to 250 meters, or about 800 feet; but when the writer visited the observatory on the 12th, Professor Matteucci stated that he had never given out this estimate. The height of the cone before the eruption was not far from, though probably in excess of, 4,265 feet (1,303 meters on the military map of 1900), while the Punta del Nasone reaches 3,779 feet.

Truncations of the same order of magnitude have occurred in 1631 and 1794.[1]

In place of the beautiful outlines which the cone of Vesuvius presented before the recent eruption (see Figs. 4 and 5), it now shows a flat dome corresponding to the larger crater and the wider radius of distribution of the ejectamenta (see Fig. 13). Its somber hue is replaced by the dim gray color of sand which seems to extend almost to its base, where before was the rich green of a sub-tropical vegetation.

Apparent relationships of events.—The recent eruption of Vesuvius belongs to the paroxysmal rather than to the explosive type, though no sharp line divides the two. The order of events has been that generally recognized to be characteristic of this type. Starting in this instance from almost absolute repose in October, 1904, activity in the crater increased gradually, and lava began to dribble from a *bocca* high up upon the inner cone late in May of the following year. Both these manifestations of returning life increased more or less steadily until early in April, 1906, when the grand stage was ushered in. It may be presumed that during these initial stages lava found its way to the *bocca* from which it issued through a comparatively narrow channel, since otherwise the weak inner cone, especially in its upper portion, could hardly have withstood its hydrostatic pressure. This channel must have been slowly but constantly widened through the gradual fusion of its walls, thus augmenting both the quantity of lava which could reach the *bocca* and the hydrostatic pressure of the column upon the now weakened walls. When the cone was no longer able to withstand the pressure, it was cleft radially to the accompaniment of light earthquakes,[2] with partial

[1] J. Roth, *loc. cit.*

[2] These earthquakes were felt in Naples, one in the late evening of the 7th, and

destruction of the crater and great reduction in its height. The exposure within the fractured crater of larger surfaces of the hitherto imprisoned lava allowed of the more rapid escape of steam, which produced much more violent explosions. The fragments and lapilli, lifted by the uprushes of steam, were distributed by a southwesterly wind over the cities at the northeastern base of the mountain and beyond. The clefts opened being on the south side of the cone, *bocche* were there formed and the lava streams following the slopes descended respectively toward Trecase, Boscotrecase, and Terzigno. The rapid descent of these great lava bodies is explained both by the steep slopes and by the head under which they flowed—the difference in elevation of the new *bocche* (near the *piano*) and the old one high up upon the central cone. The pressures now relieved, the closing phases of the eruption followed in the slow escape of the remaining steam within the lava of the crater, now doubtless covered with ash shaken down from the walls. Much of this ash was probably again and again sent up to fall in considerable part within and about the crater, the finer portions only making contribution to the comminuted material derived from the rapid expansion of the steam within the lava itself.

Mutual relationships of tectonic movements and volcanic eruptions.—Few facts have been more securely established by experience than the lack of correspondence in time of great earthquakes and volcanic eruptions, in those regions where both are common. It has even been shown by Milne that central Japan, where there are many active volcanoes, is singularly free from earthquakes. Yet, while there is apparent lack of quick sympathetic response of the one phenomenon to the other, evidence is not wanting that the influence of the one *slowly* makes itself felt upon the other. Milne has shown that the West Indian earthquakes have been broadly related in time to the greater outbursts of its volcanoes.[1] Suess[2] long ago

two in the early morning of the 8th. It may be significant that there were three main lava streams, all of which appear to have started at about this time and apparently from separate, though near-lying, *bocche*.

[1] John Milne, "Seismological Observations and Earth Physics," *Geographical Journal*, London, Vol. XXI (1903), pp. 15 ff.

[2] Ed. Suess, "Die Erbeben des südlichen Italien," *Denkschriften der Wiener Akademie, Mathematisch-Naturwissenschaftliche Klasse*, Vol. XXXIV (1872), pp. 1–32.

pointed out that the greatest of Calabrian earthquakes, that of 1783, followed upon grand eruptions of both Vulcano and Etna. The new eruption of Vesuvius, the greatest since 1631, follows close upon the greatest earthquake in near-lying territory for more than a century, not long after which had occurred the really important eruption of 1794.

ROME,
April 23, 1906.

EDITORIAL

THE ISRAEL C. RUSSELL LIBRARY

Through the generous gift of Mrs. Russell, the library of the late Professor Israel C. Russell has become the property of the University of Michigan; and by her request it will be kept separate to form the nucleus of a Departmental Library of Geology. The Regents of the University in accepting the gift authorized changes in the Museum Building—at present the home of the Geological Department—and in a few weeks the books will be arranged upon shelves in a new geological seminary room to be known as the "Israel C. Russell Room" and prepared as a memorial to this distinguished geologist. The collection which thus comes into the possession of the University of Michigan is especially rich in the separate publications of geologists; and these, like the reports and bound volumes of the collection, are to be entered in the main library catalogue of the university. An appeal will be made to working geologists here and abroad, in the hope that they will place upon their exchange lists in place of Professor Russell's name the name "Russell Library," continuing the old address (University of Michigan, Ann Arbor, Mich., U. S. A.). Contributions to the collection will be acknowledged by the University Librarian, promptly entered in the catalogue, and sent to the Russell Room, where they will at once become accessible to all students of geology. A similar request will be made of the Directors of Geological Surveys and of other geological institutions, in order that the very valuable series of their publications may be kept complete. It is thought that means will be found to continue the subscription on behalf of the Library to the important geological and geographic journals which were regularly taken by Professor Russell.

Printed address slips for mailing or expressing publications will be supplied upon application either to the University Librarian or to Professor William H. Hobbs, in care of the University. If notified in advance, the Library will generally be willing to pay the charges upon express packages.

Reviews

Geology of the Northern Adirondack Region. By H. P. Cushing. (New York State Museum *Bulletin No. 95*, 1905.) Pp. 271–454, 18 plates and 9 figures.

About a year earlier Professor Cushing published *Bulletin No. 77* of this same series, in which the "Geology of the Vicinity of Little Falls, Herkimer Co. [N. Y.]," was admirably described. The present bulletin is devoted mainly to the geology of Clinton and Franklin Counties, but one interested in the geology of the Mohawk Valley will find in the descriptions and comparisons much of genuine interest. Professor Cushing's reputation as a petrographer guarantees an accurate and valuable study of the pre-Cambrian rocks which cover so large a part of the area under consideration; but the reader interested in the structural geology and Paleozoic formations of northern New York will also find it a most interesting report. The figures, colored geological maps, and excellent plates giving views of typical outcrops of the various formations, add greatly to the attractive appearance of the bulletin.

Under pre-Cambrian history it is stated that the oldest rocks certainly recognized in the Adirondack region consist of well-banded gneisses and schists with bands of coarsely crystalline limestone, believed to be water-deposited rocks which are referred to the Grenville formation of Canada. In parts of the region is a mass of gneisses of doubtful age and formation, thought, however, to be of igneous origin, which are given the name "Saranac formation" from the exposures along the river of that name in Clinton County. Professor Cushing states that "after the present surface rocks had become deeply buried, they were invaded from beneath by a series of great igneous intrusions, broken up into patches." These igneous rocks are grouped into the following four classes: anorthosites, syenites, granites, and gabbros.

Pre-Cambrian time was very long, and the amount of erosion very great, so that Professor Cushing estimates that in this region "in all likelihood at least from three to five miles of rock thickness were worn away from the surface and perhaps considerably more, especially locally."

In early Paleozoic time a subsidence began in the northeastern part of the area and slowly moved to the southwestward. On account of overlap, the oldest Paleozoic formations, those of Lower and Middle Cambrian

age do not appear about the Adirondacks. The oldest Cambrian formation of this region is the Potsdam, a coarse, often pebbly, massive sandstone which was deposited in shallow water on the old land surface of the present Adirondack region. This was succeeded by the Beekmantown formation, composed generally of beds of sandy dolomite. In the Champlain valley the Beekmantown is overlain by a considerable thickness of quite pure marine limestones, which are very fossiliferous and known as the Chazy formation. During Chazy time there was an elevation to the southwest of the Adirondacks, followed by a depression; so that the Chazy formation does not appear on that side of the Adirondacks, and the Beekmantown is succeeded unconformably by the thin band of pure limestone known as the Lowville, which does not appear to the east and north of the Adirondacks. The Chazy limestone on the northeast and the Lowville on the southwest are both overlain by marine fossiliferous limestones, known as the Black River and Trenton formations. Through the invasion of mud the Trenton limestones pass gradually into the Utica shale, which is the youngest formation carefully described. Professor Cushing concludes that "this submergence apparently completely overswept the old Adirondack island," and "the whole of New York State would seem to have been submerged, and that for the last time in its geologic history."

C. S. PROSSER

Corundum and the Peridotites of Western North Carolina. By JOSEPH HYDE PRATT AND JOSEPH VOLNEY LEWIS. (Vol. I, N. C. Geological Survey, Raleigh, 1905.) Pp. 464, 45 plates and maps, 35 figures.

The North Carolina Geological Survey has heretofore published only "Bulletins" and "Economic Papers" of rather a preliminary nature. This volume is the first of a series of more elaborate reports on special subjects. It treats of the peridotites and associated basic magnesian rocks of North Carolina, and describes incidentally similar occurrences elsewhere in the world. The geology of the state, the petrography of the rocks, their alteration and their origin are discussed in the first part of the work. Then follow chapters on corundum, its physical and chemical properties, varieties, and uses; its occurrence and distribution; its alteration, its origin, and the method of mining and milling. The last chapter treats of chromite and other minerals of economic value which occur in the corundum-peridotite belt.

E. W. S.

The Nature of Ore Deposits. By DR. RICHARD BECK. Translated and Revised by WALTER HARVEY WEED, E.M. (*Engineering and Mining Journal*, 1905.) Pp. 685, 272 figures and map; 2 vols.

The arrangement of this work is based upon the method of deposit, instead of grouping the descriptions under the name of the predominant metal. Primary ore deposits are treated first, and are classified as "syngenetic" (formed simultaneously with the country rock) and "epigenetic" (formed later than the country rock). Syngenetic deposits are divided into "magmatic segregations" and "sedimentary ores." Epigenetic deposits are classified as either veins or deposits other than veins, of which there are four kinds. These are (*a*) impregnation of non-calcareous rocks (deposits usually in beds); (*b*) epigenetic stocks, formed by metasomatic replacement of calcareous rock; (*c*) contact metamorphic ore deposits; (*d*) ore-bearing cavity fillings.

Secondary deposits are classified as (1) residual deposits formed by alteration of primary deposits, and (2) placer deposits.

The subject of ore deposits is treated in an exhaustive way and examples are taken from all parts of the world. The translator has slightly abridged the historical matter and has revised and added a little to the descriptions of American ore deposits.

E. W. S.

Physiography of the Archean Areas of Canada. By PROFESSOR A. W. G. WILSON, McGill University, Montreal, Canada. (Eighth International Geographic Congress Report, pp. 116–35; 2 maps, 6 plates.)

The basis of this paper is the reports of explorers, together with some of the author's own work. It is an excellent discussion of the physiography of this little-known region. The geology is not taken up, but the purpose of the paper is rather to draw attention to the physiographic unity of the whole region. This broad Archean area is held to be an old peneplain which has been subjected to differential elevation, denudation, and slight incision by the sea around the margin. It is bordered by an ancient belted coastal plain. A younger coastal plain borders Hudson Bay. Glacial drift covers most of the territory, and the glaciation of this peneplain of crystalline rocks has resulted in the present lakes, muskegs, and other features of topography.

E. W. S.

Economic Geology of the United States. By HEINRICH RIES, A.M., PH.D. New York: Macmillan Co., 1905. Pp. 435, 25 plates, 97 figures.

To say that this work is designed as a textbook will give a general idea of its nature. The arrangement is somewhat different from that of other works on this subject, in that the non-metallic minerals are discussed first. The reason assigned is that the non-metallic are more important and their deposits simpler. The order of treatment is: Part I, "Coal; Petroleum, Natural Gas, and Other Hydrocarbons; Building Stones; Clay; Lime and Calcareous Cements; Salines; Gypsum; Fertilizers; Abrasives; Minor Minerals; Water; Soils and Road Materials;" Part II, "Ore Deposits; Iron; Copper; Lead and Zinc; Gold and Silver; Silver-Lead; Aluminum, Manganese, and Mercury; Minor Metals."

E. W. S.

Structural Features of the Joplin District. By C. E. SIEBENTHAL. (*Economic Geology*, Vol. I, No. 2, November-December, 1905, pp. 119–28.) *Discussion* by H. FOSTER BAIN. (*Ibid.*, pp. 172–73.)

This paper is of especial interest in that it shows a way in which incorrect conclusions may be drawn as to the throw of faults. Throws of 150 feet or more have been described for the Joplin district. Shale is found in horizontal juxtaposition with limestone strata whose normal position is 150 feet below. These conditions vary much in short distances, and the author accounts for them by showing (1) that the shale is unconformable on the limestone and was laid down on an uneven erosion surface; (2) that solution and the giving way of roofs of caverns have let blocks of strata down; and (3) that there has been faulting of much less throw.

E. W. S.

Geological Survey of North Dakota. Third Biennial Report. By A. G. LEONARD and Assistant Geologists. Bismarck, 1904. Pp. 217, 33 plates, 8 figures, 2 maps.

This work contains articles on "Lignite on the Missouri, Heart, and Cannon Ball Rivers, and its Relation to Irrigation;" "Report on the Region between the Nothern Pacific Railroad and the Missouri River;" "Topography of North Dakota;" "Geological Formations of North Dakota;" "Methods of Stream Measurements;" "The Run-off of the Streams in North Dakota."

E. W. S.

Methods and Costs of Gravel and Placer Mining in Alaska. By CHESTER WELLS PURINGTON. (U. S. Geological Survey, Bulletin No. 263, 1905.) Pp. 273, 42 plates, 49 figures, 30 tables.

The American placer miner finds himself confronted with new conditions when he goes to work in Alaska. The object of this report is to give the most expeditious way of getting out and working the auriferous material. One of the chief difficulties in working the material arises from its frozen character. There are many methods in use now in Alaska, and these are described in detail. The estimates of cost include not only labor, machinery, and arrangements of water supply, but also freight transportation and road-building. E. W. S.

Tertiary Lignite of Brandon, Vermont, and its Fossils. By G. H. PERKINS. (Bulletin of the Geological Society of America, Vol. XVI, pp. 499–516; plates 86–87; December, 1905.)

No trace of animal life appears in this lignite, but there are abundant plant remains. Exogenous trees are unusually well represented. Leaves, fruits, and bark show many of them to belong to existing genera. The age of the formation has not yet been determined. The author believes it is Miocene. E. W. S.

Sixth Annual Report of the Chief of the Mining Bureau (Philippine Islands). By H. D. MCCASKEY, Chief of the Mining Bureau, Manila, 1905. Pp. 66, 14 plates and map.

This report treats of the work of the year and of the mineral resources and mining conditions of the Philippines. American machinery and methods have done much in the development of the mining industry. The deposits are those of gold, copper, iron, and coal. E. W. S.

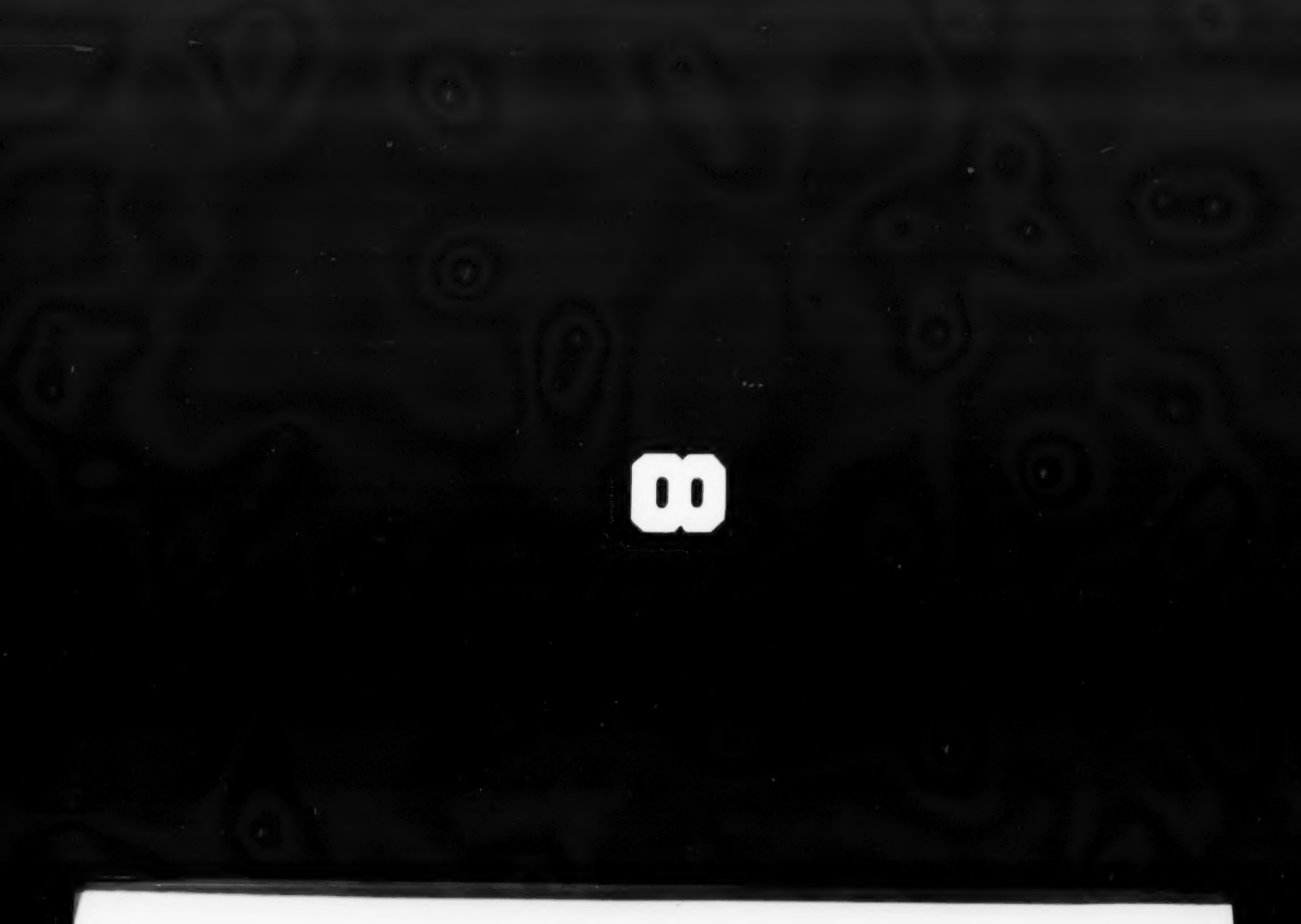
On the Glaciation of Oxford and Sutton Mountains, Quebec. By ALFRED W. G. WILSON. (Extract from *American Journal of Science*, Vol. XXI [March, 1906], pp. 196–205; 5 figures.

The upward limit of glaciation in Eastern Quebec has been put as low as 1,800 feet above sea-level by some writers. Mr Wilson finds that the highest elevations of the region are glaciated. This puts the upward limit at least as high as 2,820 feet. E. W. S.

Mineral Solution and Fusion Under High Temperatures and Pressures. By ARTHUR L. DAY. (Carnegie Institution of Washington, extracted from Fourth Year Book, pp. 224–30.)

After a statement of the new equipment of the laboratory, the results of experiments with feldspars and pyroxenes is given, and the paper closes with a brief description of the author's visit to European laboratories.

E. W. S.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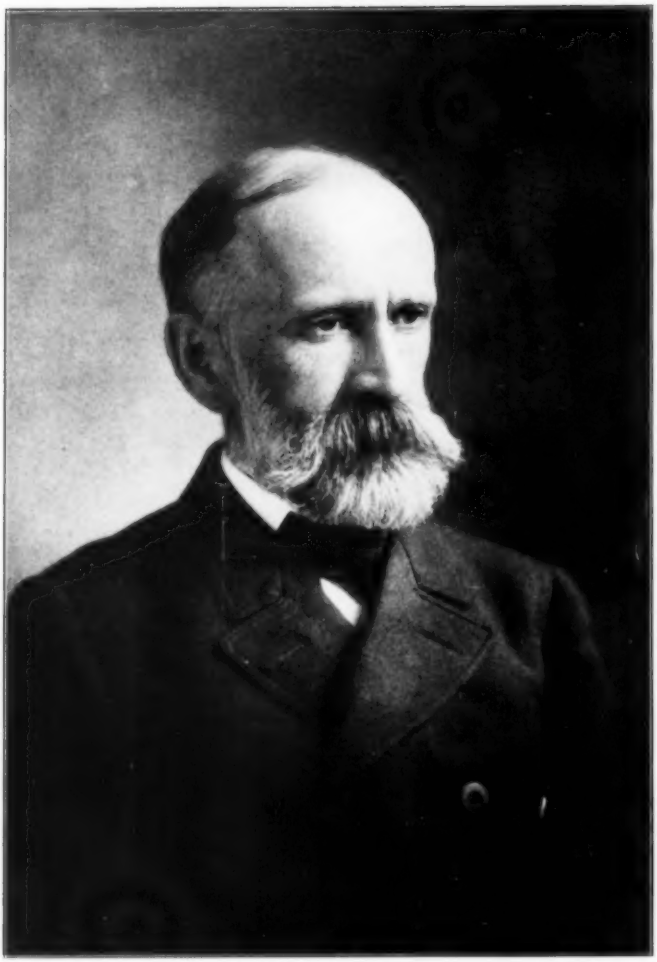

ISRAEL COOK RUSSELL